GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT INITIATION

Date: July 5, 1974

oject Title: Missile RF Systems Investigation

oject No.: A-1622

oject Director: Mr. J. M. Schuchardt

onsor: U.S. Army Missile Command

fective May 2, 1974 Estimated to run until March 2, 1975

/pe Agreement: Contract No. DAAH01-74-C-0743 Amount: $ 89,959

eports Required: Monthly Cost & Performance, Interim Technical Briefings, Final Technical Report.

onsor Contact Person (s):

Technical Matters

Chief, Advanced Sensors
Directorate
U.S. Army Missile Command
Attn: AMSMI-RER
Redstone Arsenal, Alabama
35809

Contractual Matters
(thru GTRI)

Mr. R. J. Whitcomb, ACO
ONR RR
Campus

signed to SPECIAL TECHNIQUES Division

OPIES TO:

- ☐ Project Director
- ☐ Director
- ☐ Assistant Director
- ☐ GTRI
- ☐ Division Chief (s)
- ☐ Branch Heads
- ☐ Service Groups
- ☐ Patent Coordinator
- ☐ Photographic Laboratory
- ☑ Security, Property, Reports Coordinator
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- ☐ Library
- ☐ Office of Computing Services
- ☐ Project File
- ☐ Other

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GEORGIA INSTITUTE OF TECHNOLOGY
ENGINEERING EXPERIMENT STATION

PROJECT TERMINATION

Termination memo to CES - 19 Dec. '75

Date: December 16, 1975

Project Title: Missile RF Systems Investigation

Project No: A-1622

Project Director: J. M. Schuchardt

Sponsor: U. S. Army Missile Command

Effective Termination Date: 10/15/75 (Contract Expiration)

Clearance of Accounting Charges: 10/31/75

Grant/Contract Closeout Actions Remaining: Final Invoice & Closing Documents
Gov't. Property Inventory & Cert.
Classified Material Certificate
Final Report of Inventions

Assigned to: Electromagnetics Laboratory

COPIES TO:
Project Director
Director, EES
Assistant Director
Division Chief
EES Accounting
Patent Coordinator

✓ Research Services/Photo Lab
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Other Sue Corbin

ES 402 (R10–75)

MONTHLY

COST AND PERFORMANCE

REPORT NO. 1

(2 May 1974 through 31 May 1974)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0473
(A-1622)

Prepared for

U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Reporting Period

RF testing has been performed on two antenna systems. Sum and difference patterns in two planes have been measured on indoor and outdoor antenna pattern ranges. Near field measurements and subsequent computation of far field patterns as well as conventional far field patterns have been measured at ranges of $2D^2/\lambda$ and 200 D^2/λ. Extensive cross polarized patterns have been measured at the $2D^2/\lambda$ range prior to antenna refurbishment.

Further data were taken with the radome in place with the gimbal orientation such that the antenna is looking on axis through the radome tip. Physical measurements of the radome dimensions both as to contour and thickness have also been taken.

Problems Encountered

Computer generated far field patterns obtained on the second antenna displayed a small ripple on the system axis. This has been traced to a small residual (-55 dB) effective signal over the whole 8 foot square array appearing in the recorded data. Suppression of this signal in post measurement processing improved the calculated patterns. Calibration and processing improvements are currently being implemented.

Work to be Performed in the Next Reporting Period

Cross polarized antenna patterns will be measured without the polarization grid. The grid removal technique will involve selecting the proper glue solvent which is in turn dependent on the grid material itself. The resolver will be further characterized by detailed RF phase and amplitude signal measurements and mechanical measurements.

As a result of discussions with MICOM personnel, a detailed series of tests on the electronics section of the equipment will be prepared.

Cost Information

The following charges have been incurred against the contract during the period 2 May through 31 May 1974.

Personal Services (PS)	$ 9,353.54
Materials and Supplies	134.08
Overhead (@ 65% of PS)	6,079.80
Retirement (@ 8.77% of PS)	820.30
TOTAL	$16,387.72

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Engineers	$3,538.21	238
Senior Research Engineers	2,171.12	190
Research Engineers	2,813.02	316
Student Assistants	589.87	184
Technicians, Machinists	123.17	14
Clerical	118.15	30
TOTAL	$9,353.54	972

The current financial status of the contract is as follows:

	Budget	Expended	Free Balance
Personal Services (PS)	$47,050.00	$ 9,353.54	
Materials and Supplies	2,500.00	134.08	
Travel	5,700.00	0.00	
Computer	0.00	0.00	
Overhead	30,583.00	6,079.80	
Retirement	4,126.00	820.30	
AS PROPOSED*	$89,959.00		
Partial Funding	$33,000.00	$16,387.72	$16,612.28

Based on present partial funding, the funding and equivalent man hours are not sufficient to complete the task. Should the remaining approximately $67,000 00 be funded, the resulting remaining funding and hours would be sufficient to complete the task. Approximately 18% of the proposed task has been completed.

*As given in letter dated May 29, 1974 from M. W. Long to Mr. Sharp.

MONTHLY

COST AND PERFORMANCE

REPORT NO. 2

(1 June 1974 through 30 June 1974)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743
(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During this Reporting Trip

Travel to AFAL Wright Patterson AFB and subsequent discussions with Air Force Personnel provided additional information concerning previous testing on the unit in question. A visit at Georgia Tech by Army personnel also provided additional information. This information will be used in preparation of future test plans. Additional reports documenting these tests were requested from the Contract Technical Officer.

An assessment of the polarization grid identified the material and a suitable solvent was also identified. In using this solvent to remove the grid the cloth end tended to fray. As a result, a technique of dipping the assembly in a container of liquid nitrogen and then prying the cloth and glue off together in one piece was used. The entire assembly came off in one piece and can be reused.

Underneath the polarization grid the reflector proved to be a polished aluminum spinning. It appears to have a very low surface error. Also visible under the grid is a small crack in the feed wave guide assembly. This crack will be investigated further.

The mechanically rotating RF assembly has been completely disassembled and the important RF dependent dimensions noted. Drawings of these units are in preparation.

Problems Encountered

Mechanical and RF testing proceeded with no significant problems. Documentation available from previous efforts is not anticipated to be available to the Georgia Tech Staff until early July. Preparation of test plans for further measurements will begin as soon as the material is available.

Work to be Performed in the Next Reporting Period

With the polarization grid removed, antenna patterns on the $2D^{2}/\lambda$ range will be measured to assess cross polarization response and compared to those already taken with the grid in place. Feed measurements (without the reflector) are also planned. The documentation of mechanical measurements will be continued.

A formal briefing for 9 July at Redstone Arsenal has been called. Preparation for this presentation will be undertaken.

Cost Information

The following charges have been incurred against the contract during the period 1 June through 30 June 1974.

Personal Services (PS)	$ 4,474.66
Materials and Supplies	93.30
Overhead (@ 65% of PS)	2,908.53
Retirement (@ 8.77% of PS)	392.43
Travel	213.57
TOTAL	$ 8,082.49

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Engineers	$ 626.40	42
Senior Research Engineers	1,927.32	169
Research Engineers	1,637.63	184
Student Assistants	177.40	56
Technicians, Machinists	-0-	-0-
Clerical	105.91	27
TOTAL	$ 4,474.66	478

The current financial status of the contract is as follows:

	Budget	Expended	Free Balance
Personal Services (PS)	$ 47,050.00	$ 13,828.20	$ 33,221.80
Materials and Supplies	2,500.00	227.38	2,272.62
Travel	5,700.00	213.57	5,486.43
Computer*	0.00	0.00	0.00
Overhead	30,583.00	8,988.33	21,594.67
Retirement	4,126.00	1,212.73	2,913.27
	$ 89,959.00	$ 24,470.21	$ 65,488.79

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 27% of the proposed task has been completed.

* Approximately $800.00 has been encumbered to date.

MONTHLY

COST AND PERFORMANCE

REPORT NO. 3

(1 July 1974 through 31 July 1974)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743
(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Reporting Period

Presentations describing the work performed to date at Georgia Tech were given to two groups at Redstone Arsenal on 9 July and 17 July. Portions of the briefing material are included as an attachment. Subsequent to these meetings, separate visits from Messrs. R. Heinard, HDL, C. Norton, ECOM and D. Hogan, MICOM were held at Georgia Tech to discuss matters relating to this program.

Antenna measurements without the grid in place have been performed. The reflector has been disassembled and a mandrel machined to the contour of the reflector has been prepared to be used to straighten the reflector edges. The feed has been removed for radiograph analysis and antenna pattern measurements. Phase and amplitude RF measurements on the mechanically rotating assembly have been taken at f_o and VSWR has been measured across the entire RF band.

A thorough review of the literature made available of previous test efforts has been made, and planning for future program phases is underway.

The mathematical model of the angle tracker reveals that the RF signal which emerges at the output of the RF hybrid can be viewed as a carrier - whose amplitude is proportional to the sum signal - and a pair of sidebands - separated in frequency by the resolver rotation frequency and whose amplitudes are proportional to the combined difference signals. A key point to note is that this representation differs significantly from a conventional conical scan system for angles off boresight approaching the sum half power beam width because it is in this region that the difference signal levels can exceed - 6 dB relative to the sum or the sidebands can exceed - 6 dB relative to the carrier. When AM sidebands exceed -6 dB relative to the carrier the carrier is said to be overmodulated and the resulting carrier envelope detected by the receiver becomes distorted. In this case this means angle tracking errors can result. Quantitative angle tracking effects are now being investigated using a computer to generate these complex signals. Receiver output in the form of angle output voltage versus angle off boresight and envelope amplitude and phase versus azimuth and elevation coordinates for various system parameters are being computed.

Problems Encountered

Mechanical and RF testing proceeded with no significant problems. Discussions were held during this month with Army personnel concerning additional measurements on another system. Such measurements will be performed in

August and are expected to interrupt the normal schedule one to two weeks.

Work to be Performed in Next Reporting Period

Mechanical reassembly with a refurbished reflector is planned. Computer aided analysis of the angle trackers will continue. Antenna patterns of the additional missile hardware will be taken. Future planning will include a visit to Redstone Arsenal to review the Air Force work.

Cost Information

The following charges have been incurred against the contract during the period of 1 July through 31 July 1974.

Personal Services (PS)	$ 6,825.98
Materials and Supplies	109.75
Overhead (@ 65% of PS)	4,436.89
Retirement (@ 8.77% of PS)	598.64
Travel	101.37
TOTAL	$12,072.63

The breakdown of personal services is as follows:

	Dollars	Approximate Man Hours
Principal Research Engineers	$ 608.12	41
Senior Research Engineers	2,367.20	207
Research Engineers	2,841.34	319
Student Assistants	756.70	236
Technicians, Machinists	160.50	18
Clerical	92.12	24
TOTAL	$6,825.98	845

The current financial status of the contract is as follows:

	Budget	Expended	Free Balance
Personal Services (PS)	$ 47,050.00	$20,654.18	$ 26,395.82
Materials & Supplies	2,500.00	337.13	2,162.87
Travel	5,700.00	314.94	5,385.06
Computer*	0.00	245.06	- 245.06
Overhead	30,583.00	13,425.22	17,157.78
Retirement	4,126.00	1,811.37	2,314.63
	$ 89,959.00	$36,787.90	$ 53,171.10

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 40% of the proposed task has been completed.

*Approximately $800.00 has been encumbered to date.

A-1622

MONTHLY
COST AND PERFORMANCE
REPORT NO. 4

(1 August 1974 through 31 August 1974)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743
(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Reporting Period

Antenna measurements were made on additional missile hardware in early August. Both L and X band patterns were run as well as L band antenna VSWR. This equipment has been returned to MICOM.

Discussions were held on 13 August at MICOM with Army and Air Force personnel to finalize electronics tests and test priorities. A number of tests were agreed on. Scheduling and budgeting of this test effort at Georgia Tech is underway and is expected to be finalized shortly after the electronics is received at Georgia Tech.

Prior to the reassembly of the refurbished reflector/feed assembly, individual antenna amplitude and phase patterns on the feed alone were taken. These data revealed the sum and difference feeds had colocated phase centers approximately 0.200 inches behind the feed splash plate. This location is very near the reflector focal point. The sum illumination had 6 to 10 dB variations across the angular region subtended by the reflector due to the splash plate. It was more tapered at the edge in the azimuth plane than the elevation plane accounting for the differences in the far field patterns. The azimuth difference feed pattern null at boresight was somewhat deeper (30 dB) than the elevation difference feed pattern null which was 25 dB deep.

Trips were taken to the AF-EWES at General Dynamics, Fort Worth, Texas to examine the electronics and to get the latest operational status and to participate in the dismantling for shipment to Georgia Tech. The equipment is expected to arrive on or about 6 September 1974 at Georgia Tech.

One important aspect of the angle tracker computer-aided analysis was to ascertain the effects of RF phase shift of signals occurring prior to

the resolver/hybrid components. Preliminary calculations have shown that as the sum signal is phase shifted (with both difference signals remaining unchanged) the angle output voltage decreases approximately as the cosine of the phase shift. Hence for small phase shifts (say less than 10 degrees) system performance is unaffected. This also eases the problem of repairing the severed coax cable in the feed assembly.

Problems Encountered

The salary rates affecting the personal service amounts starting next month (September) will reflect a 5 to 6% salary increase for project personnel as well as most State employees as authorized by the Georgia Legislature; consequently the man-hours/dollar amounts will be somewhat different for the rest of the program.

Work is underway at the transmitting end of the Engineering Experiment Station's outdoor antenna range that will delay testing of the refurbished antennas out of doors. This work was scheduled previously and will result in a fully automated station remotely operated from the receiving site. However, some tests will be performed on the outdoor $2D^2/\lambda$ range and indoors on the compact range.

Work to be Performed in Next Reporting Period

Antenna patterns on the refurbished antenna will be completed. The electronics should be received and the testing effort started.

Cost Information

The following charges have been incurred against the contract during the period of 1 August through 31 August 1974.

Personal Services (PS)	$ 5,913.90
Materials and Supplies	378.94
Overhead (@ 65% of PS)	3,844.03
Retirement (@ 8.77% of PS)	518.65
Travel	321.04
TOTAL	$10,976.56

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$ 665.17	45
Senior Research Engineers	1,831.12	160
Research Engineers	3,059.46	344
Student Assistants	271.40	85
Technicians, Machinists	0	0
Clerical	86.75	22
TOTAL	$5,913.90	656

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$47,050.00	$26,568.08	20,481.92
Materials & Supplies	2,500.00	716.07	1,783.93
Travel	5,700.00	635.98	5,064.02
Computer*	0.00	767.01	-767.01
Overhead	30,583.00	17,269.25	13,313.75
Retirement	4,126.00	2,330.02	1,795.98
TOTAL	$89,959.00	$48,286.41	$41,672.59

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 54% of the proposed task has been completed.

*Approximately $1,000.00 has been encumbered to date.

File: A-1622

MONTHLY

COST AND PERFORMANCE

REPORT NO. 5

(1 September 1974 through 30 September 1974)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743
(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Reporting Period

The electronics were received at Georgia Tech on 6 September. After unpacking, an examination revealed only a few peripheral wires had been broken; these were easily repaired. The equipment has been set up in an approved strong-room laboratory permitting a permanent test setup to be made and easier user access.

A thorough checkout of the AF rack and interface cables was made and the entire assembly was successfully activated. Initial systems checks indicate RF lock, doppler tracking and angle tracking circuits are performing properly. Simulated angle tracking RF signals for test purposes are being generated using the unit's resolver assembly to properly modulate the RF signal. Detailed examination of circuit performance by stages and circuit board is underway.

Discussions were held with Army and Raytheon personnel concerning differences in, and, questions relating to the servo loop block diagrams. Component tests were performed to provide additional data for further analysis. Gimbal drive motor parameters were measured as follows:

Armature Resistance	Ra ≈ 25 ohms
Motor Inductance	La ≈ 3.9 millihenries
Back EMF Constant	K_b ≈ 3.8 volts/1000 rpm
Torque Constant	K_T ≈ 4.4 oz-in/amp.
Gimbal Gear Ratio	
Inner Axis	208:1
Outer Axis	199:1

A detailed examination of the cloth/polarization grid has yielded these parameters:

Material - Fiberglass, non-coated, plain weave, 4.4 oz/yd^2

Weave

Warp direction: 47.5 ends per inch, 4 yarns of white continuous filament, very low twist yarn. Every 5th yarn is blue fiberglass twisted around a .004 inch diameter copper wire with some unidentified adhesive. Interval from blue yarn to white yarn is approximately 50% larger than the interval from white yarn to white yarn.

Filling Direction: 50 picks per inch of white yarn, continuous filament, very low twist.

Problems Encountered

Antenna testing with the refurbished antenna has been held up until early October to permit a modified short range to be specially set up to conduct antenna tests for this program. Further delays are not anticipated.

Cost Information

The following charges have been incurred against the contract during the period of 1 September through 30 September 1974.

Personal Services (PS)	$ 7,297.00
Materials and Supplies	215.26
Overhead (@ 65% of PS)	4,743.06
Retirement (@ 8.77% of PS)	639.95
Travel	796.75
TOTAL	$13,692.02

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$ 585.81	38
Senior Research Engineers	2,370.04	191
Research Engineers	3,168.80	326
Student Assistants	949.75	298
Technicians, Machinists	102.33	11
Clerical	120.27	28
TOTAL	$7,297.00	892

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$47,050.00	$33,762.68	$13,287.32
Materials & Supplies	2,500.00	890.59	1,609.41
Travel	5,700.00	1,432.73	4,267.27
Computer*	0.00	1,256.15	-1,256.15
Overhead	30,583.00	21,945.77	8,637.23
Retirement	4,126.00	2,960.99	1,165.01
TOTAL	$89,959.00	$62,248.91	$27,710.09

*Approximately $1,400.00 has been encumbered to date.

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 69% of the proposed task has been completed.

Monthly

COST AND PERFORMANCE

REPORT NO. 6

(1 October 1974 through 31 October 1974)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743
(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Reporting Period

The detailed examinations of the electronics has continued throughout this reporting period. In order to perform these examinations, the circuits to be investigated have been divided into the following general groups:

1. VFO loop (including 250 kHz IF)
2. IF amplifiers
3. Target/noise tracking and AGC circuits.

The efforts thus far have been concentrated on the VFO loop and IF amplifiers. A stage-by-stage analysis is being performed. The objectives are to determine the performance characteristics of each stage and to determine the overall performance characteristics of each circuit board. The information being collected is in general new and the test procedures have been designed to complement previous measurements. It is estimated that the detailed analysis efforts are approximately 30 percent complete.

The gain of the target 10 MHz IF amplifier appears to have deteriorated. (Note that gain defined here is obtained from $20 \text{ Log } (V_{out}/V_{in})$, and it does not take the impedances of the input or output circuits into consideration. Thus, this measure is not a true power gain.) The first two stages of the target IF amplifier form a cascode amplifier, and its gain is approximately 8 dB at the center frequency. The reference 10 MHz IF amplifier contains a similar cascode amplifier, and its gain is approximately 12 dB. Comparing these cascode amplifiers implies that the one in the target channel may have deteriorated. It is believed that a tube (or tubes) may be deteriorating. No replacement tubes are available at this time.

The other circuits that have been investigated appear to be behaving normally. Slight degradations have been noted, but nothing that would seriously affect the overall system operation.

Testing of the refurbished antenna in the principal and 45° planes has been completed. Patterns were made with and without the polarization grid for parallel and cross polarization. Depending on the plane (AZ, EL + 45°, -45°) or the pattern (sum, AZ difference or EL difference), cross polarization rejection improvement in no case exceeded 16 dB in a sector defined to be $\pm$ 12 degrees off boresight. The grid introduced a gain loss of approximately 0.3 dB.

In the 45 degree planes these data show that the maximum cross polarization level occurred when the transmitter was looking directly into the feed system not shielded by the subreflector, that is, in the 70-90° sector off boresight.

Informal project reviews were held at Huntsville this month. Preliminary reports describing recent antenna pattern test data and angle tracker waveform comparisons and electronics test data were handed out.

Problems Encountered

Personal service expenditures up to this month have, in general, exceeded a linear projected rate based on a 10 month effort. The rate has been exceeded in order to complete the major effort in about 8 months to allow relinquishment of the equipment for the next user. This month reflects a substantially reduced level of activity - notably in the mechanical area. The mechanical effort has been primarily completed with the completion of the reflector refurbishment and the accompanying documentation. The remainder of the test program, pending modification, will be devoted to electronics and RF component testing on the bench at a projected rate approximately at this month's level.

Work to be Performed in Next Performing Period

Input filters from both the front and rear channels will be measured. Mixer noise figure measurements are planned. Testing of further electronic assemblies will continue. Discussions with Army officials are planned to finalize future measurement and analysis efforts.

Cost Information

The following charges have been incurred against the contract during the period of 1 October through 31 October 1974.

Personal Services (PS)	$3,279.43
Materials and Supplies	259.28
Overhead (@ 65% of PS)	2,131.63
Retirement (@ 8.77% of PS)	287.61
Travel	85.66
TOTAL	$6,043.61

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$ 132.86	9
Senior Research Engineers	955.50	77
Research Engineers	1,779.93	186
Student Assistants	264.60	76
Technicians, Machinists	57.44	11
Clerical	89.10	19
TOTAL	$3,279.43	378

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$47,050.00	$37,042.11	$10,007.89
Materials & Supplies	2,500.00	1,149.87	1,350.13
Travel	5,700.00	1,518.39	4,181.61
Computer	0.00	1,428.35	-1,428.35
Overhead	30,583.00	24,077.40	6,505.60
Retirement	4,126.00	3,248.59	877.41
TOTAL	$89,959.00	$68.464.71	$21,494.29

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 76% of the proposed task has been completed.

MONTHLY

COST AND PERFORMANCE

REPORT NO. 7

(1 November 1974 through 30 November 1974)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743

(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Reporting Period

RF testing of the front-end components has been performed. Tests have included: resolver VSWR and insertion loss, hybrid insertion loss, input filter VSWR and insertion loss, mixer dynamic range measurements.

The detailed examinations of the electronics have continued throughout this reporting period. The stage-by-stage analyses of the IF amplifiers have been completed, and the efforts are now being concentrated on the VFO loop, the target/noise tracking circuits, and the AGC circuits. It is estimated that the detailed analysis efforts are approximately 60% complete.

It was discovered that the plate lead for 1.8 MHz oscillator used in the 9.8 to 8 MHz down-converter was broken at the base of the tube. The tube had been "cocked" in its socket so that the plate lead could make contact. In addition, the screen grid lead had previously been broken at the base of the tube, and a repair for this break had been attempted. However, the screen grid lead was making contact intermittently due to a cold solder joint. Both leads have been soldered, and the tube is functioning normally. Epoxy will be applied to these leads to provide strain relief, but it is believed that the repairs may fail if the system is subjected to mechanical vibration or stress. It would be extremely advantageous to obtain a replacement tube.

While performing the investigations on the 1.8 MHz IF amplifier, a lead on the 200 pF coupling capacitor to the final stage was broken. The defective capacitor was replaced with a similar item, and correct circuit performance has been reestablished.

In general, the data obtained from the 10 MHz IF preamplifiers and mixers agree closely with data from previous measurements. Gain compression levels for both front (target) and rear (reference) channels have been identified as being due entirely to the preamplifiers themselves. The mixer output is linear up to 0 dBm RF input levels. The mixer effective conversion loss (IF power at the preamplifier first stage grid to RF power at mixer input) was measured to be nominally 24 dB for both mixers. This loss is attributed to about 10-15 in the down conversion process and 10 dB

in the lumped constant IF combining network between the mixer outputs and the preamplifiers first stage grid. Another factor could be that the LO drive has been set to yield a low noise figure and is perhaps below a level yielding a high conversion loss.

Several visiting groups were at Georgia Tech to discuss their participation. Approximately 4 days were devoted to assisting these government and contractor personnel in their efforts.

Problems Encountered

A damaged but still working tube (V5 on board A3) has been noted and a replacement requested. Approximately one man week was spent isolating the intermittent condition which was finally attributed to a cold solder joint in a previous repair job.

Work to be Performed in Next Reporting Period

Individual component/assembly testing will be completed and a reassembly effort begun. Planning and coordintion of system testing in the first quarter of 1975 will continue.

Cost Information

The following charges have been incurred against the contract during the period of 1 November through 30 November 1974.

Personal Services (PS)	$3,264.47
Materials and Supplies	181.86
Overhead (@ 65% of PS)	2,121.91
Retirement (@ 8.77% of PS)	286.29
Travel	317.73
TOTAL	$6,172.26

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$ 132.85	9
Senior Research Engineers	1,019.62	82
Research Engineers	1,639.42	179
Student Assistants	390.05	111
Technicians, Machinists	0	0
Clerical	82.53	18
TOTAL	$3,264.47	399

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$47,050.00	$40,306.58	$ 6,743.42
Materials and Supplies	2,500.00	1,331.73	1,168.27
Travel	5,700.00	1,836.12	3,863.88
Computer	0.00	1,680.57	-1,680.57
Overhead	30,583.00	26,199.31	4,383.69
Retirement	4,126.00	3,534.89	591.11
TOTAL	$89,959.00	$74,889.20	$15,069.80

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 83% of the proposed task has been completed.

A-1622

Corrected Copy

MONTHLY

COST AND PERFORMANCE

REPORT NO. 8

(1 December 1974 through 31 December 1974)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743

(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Reporting Period

Testing of the passive RF components including the waveguide mixers was completed. Noise figure measurements were made on the front and rear mixer/preamplifier units. The average SSB noise figure for the front unit was 12.8 dB while the rear unit showed a slightly poorer value of 13.8 dB. System noise figure would still be higher because of losses from the antenna to the mixer input. While all of these losses are not known for the rear (reference) path, the front channel losses are known to be approximately 2.1 dB. Thus the effective system noise figure of the front channel is 14.9 dB.

The detailed examinations of the electronics have continued throughout this reporting period. The stage-by-stage analyses of the IF amplifiers, target/noise tracking circuits, and the AGC circuits have been completed. A few minor tests remain to be performed on the VFO and AGC circuits, but these tests can best be carried out after the system is reassembled. With the exception of the L.O. and two RF mixers, the electronics unit has been reassembled. It is estimated that the detailed analysis efforts are approximately 95% complete.

Several light repairs to the hardware were necessary for continued operation. Epoxy was applied as strain relief for the 1.8 MHz oscillator tube leads in the 9.8 to 8 MHz down-converter. Strain relief was also applied to the mixer tube located on the 250 kHz IF amplifier chassis. In both cases proper tube operation was established after the epoxy application. A series limiting diode (D5 on A4) was found to be faulty, thereby causing improper discriminator performance. The faulty diode was replaced with a similar item and proper circuit operation was reestablished.

Data obtained, where comparable, from the AGC, target/noise, and VFO testing generally agreed closely with data taken from previous measurements, however, additional new data on these circuits has also been obtained. As an example, a Phase Locked Loop (PLL) technique was used to gather VFO data. The PLL allowed the VFO output frequency to be directly observed as an analog voltage. The VFO frequency was measured as a function of the reactance tube excitation. Photographs were made of these responses both to externally

generated signals and the internal phantastron sweeper. The curves were made for several settings of center frequency; that is, with the variable capacitor set for several representative frequency values.

A series of preliminary informal reports documenting these and other test areas are attached. They are: Seeker Waveforms - Measured and Calculated, Passive RF Component - Including Mixer Test Data, and Antenna Pattern Measurements - Before and After Refurbishment.

A portion of the mixer evaluation was devoted to investigating the local oscillator operation. A more detailed block diagram was developed and is included in the test data report. The unit consists of a multiplier chain having a multiplication ratio of 486:1. The low frequency portions of the circuit are adequately defined in previous documents and were verified during this effort. RF power at the S-band subharmonic was measured at approximately + 20 dBm with the final harmonic upconversion reducing this to the +0 to 6 dBm previously reported. This latter value was not verified in this effort due to an unexpected turn-on problem of the L.O. while on the bench out of the missile main frame. The nature of this problem is discussed below.

Problems Encountered

The operation of the local oscillator on the bench apparently requires a logic signal in order to permit the S-band RF subharmonic power to be applied to the final waveguide tripler. Previous documentation was unclear in this area. As a result RF power at the L.O. frequency was not measured on the bench. This will be delayed until the reassembly effort. The nature of the logic signal (if any) and L.O. power will then be measured.

The holidays in December have slowed the technical effort somewhat, but no other problems have been encountered.

Work to be Performed in Next Reporting Period

Reassembly will be completed and work on the final report begun.

Cost Information

The following charges have been incurred against the contract during the period of 1 December through 31 December 1974.

Personal Services (PS)	$3,065.79
Materials and Supplies	230.00
Overhead (@ 65% of PS)	1,992.77
Retirement (@ 8.77% of PS)	268.87
Travel	21.71
TOTAL	$5,579.14

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$ 273.74	19
Senior Research Engineers	914.84	74
Research Engineers	1,587.15	173
Student Assistants	114.71	33
Technicians, Machinists	0	0
Clerical	173.59	38
TOTAL	$3,064.03	337

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$47,050.00	$43,372.37	$ 3,677.63
Materials and Supplies	2,500.00	1,561.73	938.27
Travel	5,700.00	1,857.83	3,842.17
Computer	0.00	1,680.57	-1,680.57
Overhead	30,583.00	28,192.04	2,390.96
Retirement	4,126.00	3,803.76	322.24
TOTAL	$89,959.00	$80,468.30	$ 9,490.70

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 89% of the proposed task has been completed.

A-1622

MONTHLY
COST AND PERFORMANCE
REPORT NO. 9

(1 January 1975 through 31 January 1975)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743
(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Reporting Period

The detailed examinations of the electronics were completed, and the unit was reassembled during the early part of this reporting period. In addition to this technical activity a two day meeting was held at Georgia Tech. Attendees were seven government personnel interested in the technical aspects of this program.

Upon reassembly, a component measurement of the RF characteristics of the local oscillator was made. The tests showed the voltage that was referred to as a logic signal in the previous report, was a 6 Vdc voltage that came on with the B+ voltage. Its function, though, is still not clear. Spectrum and power measurements showed that proper LO operation was obtained after reassembly.

Problems Encountered

During the reassembly effort, a program was undertaken to reestablish proper operation of the unit at a system level. Doppler target lock-on was achieved but the unit failed to track shifts in doppler frequency. The problem was traced to the 250 kHz discriminator, specifically to the discriminator driver tube, V_5 on Chassis A4. Two leads on this tube had broken and been repaired before the unit was shipped to Georgia Tech. The plate lead was broken off flush with the base of the tube, and the original repair failed. At this time, proper operation of the tube has been reestablished but the plate lead connection is still quite sensitive to shock. Efforts are currently in progress to provide a reliable connection, strain relieved so as to insure durability of the circuit. With the exception of the discriminator, all of those subsystems removed for detailed analysis are functioning properly.

The attached financial information reflects an overrun condition in the personal services relative to the initially budgeted amounts. Unexpected unreported student assistant personal services charges were not reported for December due to holiday delays. The significant increase from the previous report reflects full-time usage of the student assistants

in December during the holiday break. It is anticipated that the remaining travel and materials and supplies funds will be apportioned to cover the remaining expenses of final report preparation.

Work to be Performed in Next Reporting Period

Final report preparation will occupy the major portion of the time.

Cost Information

The following charges have been incurred against the contract during the period of 1 January through 31 January 1975.

Personal Services (PS)	$3,794.15
Materials and Supplies	168.84
Overhead (@ 65% of PS)	2,466.20
Retirement (@ 8.77% of PS)	332.75
Travel	91.36
TOTAL	$6,853.30

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$ 0.00	0
Senior Research Engineers	511.08	41
Research Engineers	1,745.15	190
Student Assistants	1,487.76	428
Technicians, Machinists	0.00	0
Clerical	50.16	11
TOTAL	$3,794.15	670

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$47,050.00	$47,166.52	$ -116.52
Materials and Supplies	2,500.00	1,730.57	769.43
Travel	5,700.00	1,949.19	3,750.81
Computer	0.00	1,685.35	-1,685.35
Overhead	30,583.00	30,658.28	-75.28
Retirement	4,126.00	4,136.50	-10.50
TOTAL	$89,959.00	$87,326.41	$2,632.59

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 97% of the proposed task has been completed.

A-1622

MONTHLY
COST AND PERFORMANCE
REPORT NO. 10 and 11

(1 February 1975 through 28 February 1975)
(1 March 1975 through 31 March 1975)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743
(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Reporting Period

This report covers two months technical effort and includes separate cost information for the two months. The March cost data includes new financial data based on additional funding.

A meeting was held at Georgia Tech with Army personnel and contractor representatives from Raytheon on 3 and 4 February. A mutual briefing of work performed on related contracts was presented and future testing efforts discussed. In the remainder of February, the principal technical effort involved preparation of the final report describing work performed during the first 10 months of the program. Draft copies of this report were mailed on 14 March.

During March, the continued technical effort was concentrated on mating the RF section with the electronics section and establishing proper operation of the complete system. Several problems were encountered and corrected. First, the discriminator driver tube, 6Zh45 B-V, was inoperative because of a broken lead. This tube was replaced with a spare 6Zh5 B-V and the discriminator driver performance characteristics were measured with the new tube. The performance characteristics obtained with the new tube are essentially identical to the original performance characteristics.

Second, a lead was broken on the tube in the final amplifier stage of the VFO up-converter. The original tube, a 6Zh45 B-V, was replaced with a spare 6Zh1 B-V. After the tube was replaced, the circuit performance obtained was verified to be essentially identical to the original circuit performance.

Third, the center contact on the outer gimbal position potentiometer was not making contact with the resistance element. The potentiometer was disassembled and satisfactory repair was accomplished.

Finally, one half of the frequency feedback/position potentiometer has been inoperative since before the AF interface rack was fabricated. As a result the velocity gate has only had rate control. The potentiometer was disassembled and the resistance element was repaired. The velocity gate now operates as originally designed, with position control. In addition, the AF interface rack has been modified to accept the new mode of operation.

The doppler tracking capabilities of the complete system are currently operating normally. Satisfactory angle tracking has not been obtained.

This deficiency is being pursued, and it is estimated that the complete system check-out will be completed early in the next reporting period.

A meeting was held at Redstone Arsenal on 20 March to review future tests. Personnel from the Army, Air Force and Georgia Tech participated. Testing will commence as soon as all repairs are completed and will require 6 to 8 weeks. The measurements will include clutter characterizations with the resolver operating, RF seeker alignment and RF susceptibility testing.

Problems Encountered

The defective resolver speed control problem has been identified. The unit is basically almost worn out with the motor brushes and commutator body worn and the centrifugal switch contacts pitted and dirty. By cleaning and tightening, the unit is now working; however, an electronic regulator is being investigated.

Work to be Performed in Next Reporting Period

Repair and preliminary system assembly is estimated to be completed in early April. Clutter and high signal level measurements are planned to be performed next, provided reliable equipment operation can be maintained.

Cost Information

The following charges have been incurred against the contract during the period of 1 February through 28 February 1975.

Personal Services (PS)	$3,563.49
Materials and Supplies	201.53
Overhead (@ 65% of PS)	2,316.27
Retirement (@ 8.77% of PS)	312.52
Travel	8.68
TOTAL	$6,402.49

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$ 0.00	0
Senior Research Engineers	209.54	17
Research Engineers	2,481.67	270
Student Assistants	722.91	208
Technicians, Machinists	17.31	3
Clerical	132.06	29
TOTAL	$3,563.49	527

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$47,050.00	$50,730.01	$-3,680.01
Materials and Supplies	2,500.00	1,932.10	567.90
Travel	5,700.00	1,957.87	3,742.13
Computer	0.00	1,687.71	-1,687.71
Overhead	30,583.00	32,974.55	-2,391.55
Retirement	4,126.00	4,449.02	- 223.02
TOTAL	$89,959.00	$93,731.26	$-3,772.26

Cost Information

The following charges have been incurred against the contract during the period of 1 March through 31 March 1975.

Personal Services (PS)	$3,250.68
Materials and Supplies	704.53
Overhead (@ 65% of PS)	2,112.94
Retirement (@ 8.77% of PS)	285.08
Travel	0.00
TOTAL	$6,353.23

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$ 132.86	9
Senior Research Engineers	810.07	66
Research Engineers	1,486.26	161
Student Assistants	406.55	117
Technicians, Machinists	306.16	53
Clerical	108.78	7
TOTAL	$3,250.68	413

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$91,080.00	$53,980.69	$37,099.31
Materials and Supplies	5,800.00	2,636.63	3,163.37
Travel	7,950.00	1,957.87	5,992.13
Computer	1,600.00	1,687.71	-87.71
Overhead	59,203.00	35,087.49	24,115.51
Retirement	7,987.00	4,734.10	3,252.90
TOTAL	$173,620.00	$100,084.49	$73,535.51

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 57% of the proposed task has been completed.

MONTHLY

COST AND PERFORMANCE

REPORT NO. 12

(1 April 1975 through 30 April 1975)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743

(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed This Reporting Period

Extensive system measurements were made this month and some additional repairs were also made.

During a preliminary assembly and mounting of the antenna/gimbal on the electronics, failures of two RF cables and gimbal drive amplifier power transistors occurred. These have been repaired satisfactorily.

A key series of tests investigating various Δ/Σ ratios and the resultant AGC voltages was performed. The effect on the AGC was pronounced for Δ/Σ ratios of 0 dB $\pm$ 1 dB, however, the net IF amplifier gain change was only a few dB since the various AGC effects tended to cancel. (More detailed information on these tests is being forwarded under separate cover.)

In anticipation of upcoming RF susceptibility testing, a shielded anechoic chamber is being instrumented to provide calibrated RF fields. The frequency span is most of the VHF through X-band region.

Radome off-axis characteristics have been measured in both the azimuth and elevation planes. From these data, boresight shift versus gimbal angle and the derivative of this curve—boresight error rate versus gimbal angle—will be determined.

Problems Encountered

The numerous repairs necessary in March and April will delay shipping the equipment until the end of May.

Work to be Performed in Next Reporting Period

Further system tests are planned. Portions of these will be witnessed by Air Force and Raytheon personnel. These tests include RF susceptibility to out-of-band signals.

Cost Information

The following charges have been incurred against the contract during the period of 1 April through 30 April 1975.

Personal Services (PS)	$6,082.99
Materials and Supplies	88.50
Overhead (@ 65% of PS)	3,953.94
Retirement (@ 8.77% of PS)	533.48
Travel	53.38
TOTAL	$10,712.29

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$ 132.86	9
Senior Research Engineers	1,338.93	109
Research Engineers	1,302.72	141
Student Assistants	208.40	60
Technicians, Machinists	48.14	8
Clerical	75.97	5
TOTAL	$3,107.02	332

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$91,080.00	$60,063.68	$31,016.32
Materials and Supplies	5,800.00	2,725.13	3,074.87
Travel	7,950.00	2,011.25	5,938.75
Computer	1,600.00	1,687.71	-87.71
Overhead	59,203.00	39,041.43	20,161.57
Retirement	7,987.00	4,983.53	3,003.47
TOTAL	$173,620.00	$110,512.73	$63,107.27

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 64% of the proposed task has been completed.

A-1-

MONTHLY

COST AND PERFORMANCE

REPORT NO. 13

(1 May 1975 through 31 May 1975)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743
(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During this Reporting Period

Summary

This month extensive system measurements were made to complete Air Force and Army tests. The effort culminated with the mating of the antenna gimbal assembly and the performance of RF susceptibility and angle tracking tests in a shielded anechoic chamber. The unit was observed to be properly aligned and working by an Air Force representative from Vitro Services and was ready for shipment on 30 May.

Discussion

RF clutter and feed-through tests were conducted following test plans submitted by the Army, Air Force and Raytheon. Typically these tests used three phase locked signal generators to provide the rear reference, target and clutter (or feed-through) signals. Extensive test data were taken in the following areas:

1. Sub clutter visibility (also run with phase locked IF signal generators)
2. Rear reference feed-through
3. RF Noise effects
4. Scanner effects

As time permitted, additional component testing was performed in some circuit areas: obtaining IF transformer data and tube characteristics, and measuring an additional LO module (#5). The additional LO module frequency measured 1.6 MHz higher at the mixer than the original LO module (#3).

During the latter part of the month the RF susceptibility measurements were conducted with the equipment located in the anechoic chamber, configured for typical operation, i.e. lock onto target source and exposed to a source producing high level electromagnetic field over the frequency range of 300 GHz to 11 GHz. At the field strength levels employed, the equipment was not susceptible to high power type interference, i.e., interference which is independent of any frequency relationship between the interference signal and internally generated signals. However, the equipment was highly susceptible to spurious responses formed in the first receiver mixer. Approximately 200

responses were noted and recorded over the test frequency range. A computer program provided an identification of these responses in terms of harmonic multipliers of the interference frequency and the first mixer local oscillator frequency.

Angle tracker testing was initially slowed by two problems. First an intermittant condition in the initial servo amplifier circuits (boards F4, F5 and F6) caused a large DC offset in angle tracker voltage to the gimbal servo amplifier to exist. To solve this problem a complete disassembly of these boards was necessary. Proper operation on the bench was achieved through readjustment of leads and soldering various questionable joints. (It is assumed that this condition was the cause of two transistor failures in the inner gimbal axis.)

The second problem was associated with a circuit modification made at Boeing and not noted in the system documentation -- the addition of 3 relays packaged in 3 TO5 transistor cans located in the power supply section. These relays are operated in parallel and permit the rate gyros to be turned off during electronics testing to lessen gyro wear. This relay actuator circuit has been routed to the control panel and can now be readily operated.

Work to be Performed in Next Reporting Period

Unit delivery to the Air Force is scheduled for 4 June. Delivery will be by military airlift with pickup at Dobbins AFB, Marietta.

An informal program review is planned at Redstone Arsenal. Both technical and budgetary matters will be discussed.

The documentation effort of recent test results will continue.

Tests on other system components will now proceed.

Note: A repair check list of recent repairs is included.

30 May 1975

REPAIR CHECK LIST

Problem	Action	Status
1. Inoperative or broken vacuum tubes	Replaced units with closest equivalent	Satisfactory operation restored
a) 6Zh45B-V(V5,A4)	Replaced with 6Zh5B-V	
b) 6Zh45B-V(V4,E4)	Replaced with 6Zh1B-V	
2. Nonoperating mechanical regulator on resolver motor	Examined unit and found worn contacts, brushes and commutator	Cleaning restored operation temporarily. Long term solution is possible but not yet implemented.
3. Defective cable between IF Preamp and IF Amp	Repaired cable (overcame 15 dB loss due to break in outer conductor)	Satisfactory operation restored
4. No Position Pot voltage on outer gimbal	Partially Disassembled unit and increased wiper tension	Satisfactory operation restored (technique also applied to VFO to restore position mode
5. Severed RF cable failure and original RF cable failure	Completely disassembled RF adapters. Replaced RF cable with RG188	Satisfactory operation restored
6. Inner Gimbal power amp transistor(s) failure	Replaced transistors with suitable units. Improved heat sinking	Satisfactory operation restored (in the short run)
7. Defective relay in 5 second timer circuit	Replaced defective unit with another equivalent unit	Satisfactory operation restored

Cost Information

The following charges have been incurred against the contract during the period of 1 May through 31 May 1975.

Personal Services (PS)	$ 8,120.31
Materials and Supplies	226.49
Overhead (@ 65% of PS)	5,278.20
Retirement (@8.77% of PS)	712.15
Travel	24.67
TOTAL	$14,361.82

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$ 66.43	5
Senior Research Engineers	1,177.09	96
Research Engineers	1,087.03	118
Student Assistants	501.27	144
Technicians, Machinists	0	0
Clerical	51.40	3
TOTAL	$2,883.22	366

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$91,080.00	$68,183.99	$22,896.01
Materials and Supplies	5,800.00	2,951.62	2,848.38
Travel	7,950.00	2,035.92	5,914.08
Computer	1,600.00	1,687.71	-87.71
Overhead	59,203.00	44,319.63	14,883.37
Retirement	7,987.00	5,695.68	2,291.32
TOTAL	$173,620.00	$124,874.55	$48,745.45

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 72% of the proposed task has been completed.

MONTHLY

COST AND PERFORMANCE

REPORT NO. 14

(1 June 1975 through 30 June 1975)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743

(A-1622)

Prepared for

U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed during this Report Period

The equipment was delivered to a representative of the Air Force (George Barrow) at Dobbins, AFB in Marietta, Georgia on 4 June. Since the departure of the unit, continuing efforts are underway to formalize the results of the tests conducted during the last months that the unit was at Georgia Tech. These test results will be included in the project final report.

An informal briefing was held on 5-6 June at the Redstone Arsenal. The talks centered around the effects of modulated clutter on the AGC actions and budgetary matters.

In response to request for additional copies of the "Draft" A-1622 report, three additional copies were produced and distributed. Copies have now been sent to MICOM, MIA, Eglin AFB, and General Dynamics, Ft. Worth.

Problems Encountered

Efforts have in general been somewhat reduced this month and will continue in July because of the vacation schedules of key personnel.

Work to be Performed on Next Reporting Period

On 1-2 July portions of the technical work will be presented at an anti-radiation missile counter measures (ARM/CM) tri-service meeting.

Work has begun on the ground equipment. The TWT amplifier, magnetron, and IF amplifiers will be the items examined in detail. Initially, these components will be x-rayed to determine their physical characteristics.

Cost Information

The following charges have been incurred against the contract during the period of 1 June through 30 June 1975.

Personal Services (PS)	$ 2,567.53
Materials and Supplies	553.05
Overhead (@ 65% of PS)	1,668.89
Retirement (@8.77% of PS)	225.17
Travel	168.43
TOTAL	5,183.07

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	0	0
Senior Research Engineers	$1,327.96	108
Research Engineers	510.48	55
Student Assistants	436.60	125
Technicians, Machinists	39.92	7
Clerical	252.57	15
TOTAL	$2,557.53	310

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$91,080.00	$70,751.52	$20,328.48
Materials & Supplies	5,800.00	3,504.67	2,295.33
Travel	7,950.00	2,204.35	5,745.65
Computer	1,600.00	1,687.71	-87.71
Overhead	59,203.00	45,988.52	13,214.48
Retirement	7,987.00	5,920.85	2,066.15
TOTAL	$173.620.00	$130.057.62	$43,562.38

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 75% of the proposed task has been completed.

A-1622

MONTHLY

COST AND PERFORMANCE

REPORT NO. 15

(1 July 1975 through 31 July 1975)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743

(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During this Reporting Period

Final report planning and preparation is underway along with data reduction of previous system tests. It is suggested that the final report dealing with the airborne equipment be prepared in two volumes. Volume I would be a slightly edited version of the current draft dealing with component tests. Volume II would deal with the system tests. A separate report would be issued dealing with the ground equipment tests.

Testing of the ground equipment components has been initiated with the x-raying of the mangetron, traveling wave tube amplifier (TWT), waveguide band pass filter, and the waveguide circulators. A study was made of these data to ascertain the physical construction utilized in these devices and the appropriate circuit hookup. The magnetron has been mounted in a pulser unit for testing, but will not be tested until the early part of August. The TWT is a lightweight periodic permanent magnet (PPM) focus type, medium gain tube. It provided the following operational characteristics for the conditions noted:

- Gain: 31 dB
- Bandwidth: 3 GHz (3 dB)
- Noise figure: 26 dB
- Filament Voltage: 6.3 VAc
- Helix Voltage: 1020 VDC
- Collector Voltage: 1020 VDC
- Anode Voltage: -20 VDC

Variations from these operating voltages tended to either lower the gain, decrease bandwidth or increase noise.

The tuned cavity waveguide bandpass filter which follows the TWT amplifier is of the dual mode configuration described in Microwave Transmission Circuits, Rad Lab Series, Vol. 9, page 676. This filter has three bandpasses to which it can be tuned by varying the cavity length via a three position switch. Characteristics of this device are:

- Insertion Loss: 16 dB miminum; at each resonant frequency
- Loaded Q ($\frac{f}{\Delta f}$):
  a. Low Band: 578
  b. Middle Band: 728
  c. High Band: 421

Measurements on the circulator used between the TWT and the band pass filter have also been made. These units appear to be damaged in that the frequency tuning is off. It appears that the permanent magnets have deteriorated.

One of the rear reference antennas has been x-rayed and mechanical drawings prepared.

Problems Encountered

Because of earlier delays in the airborne hardware testing program due to equipment failures, it is desirable to extend the program at no additional cost. A request for an extension of the contract termination date from 2 September 1975 to 15 October 1975 will be initiated.

Work to be Performed in Next Reporting Period

Magnetron testing will be initiated and RF testing rear reference antenna completed. Final report activities will continue.

Cost Information

The following charges have been incurred against the contract during the period of 1 July through 31 July 1975.

Personal Services (PS)	$4,308.84
Materials and Supplies	145.55
Overhead (@ 65% of PS)	2,671.48
Retirement (@ 8.77% of PS)	377.89
Travel	0
TOTAL	$7,503.76

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	265.72	18
Senior Research Engineers	1,419.97	114
Research Engineers	1,311.30	143
Student Assistants	1,211.94	300
Technicians, Machinists	0	0
Clerical	99.91	22
TOTAL	4,308.84	597

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$91,080.00	$75,060.36	$16,019.64
Materials & Supplies	5,800.00	3,650.22	2,149.78
Travel	7,950.00	2,204.35	5,745.65
Computer	1,600.00	1,687.71	-87.71
Overhead	59,203.00	48,789.24	10,413.76
Retirement	7,987.00	6,582.80	1,404.20
TOTAL	$173.620.00	$137,974.68	$35,645.32

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 80% of the proposed task has been completed.

MONTHLY
COST AND PERFORMANCE
REPORT NO. 16

(1 August 1975 through 31 August 1975)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743

(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During this Reporting Period

Work continued this month with the ground equipment. The magnetron and the magnetron modulator circuit have been investigated. The magnetron modulator circuit is a conventional hard-tube modulator employing a variant of the 829B vacuum tube on the switch tube. An attempt to reconstruct the modulator circuit was made but insufficient hardware is available to do this with accuracy.

Measurements made on the filament transformer indicated a probable loaded voltage of 3.5 volts which was found to be adequate for proper operation of the tube. Stable pulse operation of the magnetron occurred with a cathode voltage pulse of -1750 volts. This voltage produced a current pulse of 1.2 amperes which is consistent with the generally recognized operating resistance of approximately 1500 ohms for magnetrons. Operating the tube with larger voltages (therefore larger currents) caused moding and a cessation of the RF output.

The nominal X-band frequencies of operation for the three positions of the mechanical selector switch are:

f_1

$f_1 + 30$ MHz

$f_1 + 60$ MHz

The tube, however, exhibited a high pushing factor (sensitivity to power supply settings) which could increase these values by 20 MHz.

Operating the tube with a 0.4 μsec pulse width at 500 pps, a peak pulse power of approximately 100 watts was measured.

Tests on the rear reference antenna have shown it has these nominal parameters at its design frequency.

E plane halfpower beamwidth = 72°
H plane halfpower beamwidth = 67°
Polarization = vertical
Gain = 8.2 dB
Efficiency = 77%
VSWR = 1.2:1

Problems Encountered

During photographic efforts on the bench, with the TWT glass envelope out of the magnetic structure, it was accidentally jarred and the glass envelope broken. The tube is unrepairable. All significant planned RF tests had been completed at that time. The tube has now been completely disassembled and the internal structure examined and photographed.

Work to be Performed in Next Reporting Period

The major component tests have been completed. The remaining portion of the program will be devoted to documentation and report preparation.

A briefing at Huntsville reviewing work on this program is planned for 18 September.

Cost Information

The following charges have been incurred against the contract during the period of 1 August through 31 August 1975.

Personal Services (PS)*	$4,476.90
Materials & Supplies	115.59
Overhead (@ 65% of PS)	2,909.99
Retirement (@ 8.77% of PS)	392.62
Travel	0
TOTAL	7,895.10

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$265.72	18
Senior Research Engineers	2,523.23	203
Research Engineers*	1,008.68	110
Student Assistants	500.02	124
Technicians, Machinists	97.44	15
Clerical	81.81	18
TOTAL	4,476.90	488

The current financial status of the contract is as follows:

	Budget	Expended	Free
Personal Services (PS)	$91,080.00	$79,537.26	$11,542.74
Materials & Supplies	5,800.00	3,765.81	2,034.19
Travel	7,950.00	2,204.35	5,745.65
Computer	1,600.00	1,687.71	-87.71
Overhead	59,203.00	51,699.22	7,503.78
Retirement	7,987.00	6,975.42	1,011.58
TOTAL	173,620.00	145,869.77	27,750.23

Based on the present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 84% of the proposed task has been completed.

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*Includes correction: over-charge in July of $1,044.31 and omission in June of $1,714.16.

A-1622

MONTHLY
COST AND PERFORMANCE
REPORT NO. [redacted] /7

(1 September 1975 through 30 September 1975)

MISSILE RF SYSTEMS INVESTIGATION

J. M. Schuchardt

Contract DAAH01-74-C-0743

(A-1622)

Prepared for

U.S. Army Missile Command
Redstone Arsenal, Alabama 35809

by

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Work Performed During This Reporting Period

Primary efforts have involved final report preparation and performing additional tests on the ground equipment.

Volume 1 dealing with missile components is 90% complete and is in the photo lab for layout on photographic work. Volume 2 dealing with system tests is 50% complete. Final art work is being prepared; the final text is complete. Volume 3 dealing with the ground equipment is to the same completeness state as is Volume 2.

Tests were made on the ground antenna. The unit is vertically polarized with a gain of 22dB. The azimuth beamwidth is one-half of the elevation beamwidth.

The mixer (modulator) used to generate an IF was found to have a definite low signal level threshold at -15dBm. In effect the received signal serves to bias the mixer diode as no large-level local signal is used. This threshold serves to limit the maximum range to a few hundred meters.

A presentation summarizing the total program to date was given on 18 September at MICOM to the Cross Bow S Committee.

Problems Encountered

Recent negotiations with the cognizant auditing agency have resulted in revised overhead and retirement rates. The attached financial sheet reflects recent adjustments made retroactive to 1 July 75.

Work To Be Performed In Next Reporting Period

Complete the Final Report.

Cost Information

The following charges have been incurred against the contract during the period of 1 September through 30 September 1975.

Personal Services (PS)	$ 8,371.66
Materials and Supplies	207.90
Overhead (@ 68% of PS)	6,117.02
Retirement (@8.936% of PS)	748.09
Travel	0
TOTAL	$15,444.67

The breakdown of personal services is as follows:

	Dollars	Approximate Man-Hours
Principal Research Engineers	$1,328.55	90
Senior Research Engineers	3,133.30	252
Research Engineers	2,742.39	300
Student Assistants	112.73	28
Technicians, Machinists	646.63	100
Clerical	408.03	90
TOTAL	$8,371.66	860

The current financial status of the contract is as follows:

	Budget	Expeneded	Free
Personal Services (PS)	$ 91,080.00	$ 87,908.92	$ 3,171.08
Materials & Supplies	5,800.00	3,973.71	1,826.29
Travel	7,950.00	2,204.35	5,745.65
Computer	1,600.00	1,687.71	-87.71
Overhead	59,203.00	57,816.24	1,386.76
Retirement	7,987.00	6,668.94	1,318.06
TOTAL	$173,620.00	$160,259.87	$13,360.13

Based on present full funding, the funding and equivalent man hours are sufficient to complete the task. Approximately 92% of the proposed task has been completed.

File: A-1622

SPECIAL TECHNICAL REPORT

MISSILE RF SYSTEMS INVESTIGATION

Briefing Material of Work Till 9 July 1974

J. M. Schuchardt
J. M. Newton

A-1622 TR-1

Systems and Techniques Department
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

MISSILE RF SYSTEMS INVESTIGATIONS

SPECIAL PROJECT OF THE

SYSTEMS AND TECHNIQUES DEPARTMENT
ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY

DR. R. C. JOHNSON, DEPT. MGR.
J. M. SCHUCHARDT, PROJ. DIR.

PARTICIPANTS

SPECIAL TECHNIQUES DIVISION J. W. DEES	● PROJECT DIRECTOR ● SEEKERS ● RF COMPONENT MEASUREMENTS
RADAR DIVISION H. A. ECKER	● NEAR FIELD MEASUREMENTS ● RADAR/ECM
SENSOR SYSTEMS DIVISION R. M. GOODMAN	● MECHANICAL SUPPORT ● FAR FIELD MEASUREMENTS ● SIMULATIONS
COMMUNICATIONS DIVISION D. W. ROBERTSON	● ELECTRONIC CIRCUIT MEASUREMENTS

AREAS OF INVESTIGATION IN THIS PROGRAM

- ANTENNA
- PASSIVE MICROWAVE PARTS
- ELECTRONICS
- MANUFACTURING TECHNOLOGY ASSESSMENT

GEORGIA TECH PROGRAM TO DATE

- DETAILED ELECTRICAL AND MECHANICAL MEASUREMENTS OF COMPONENTS AND SUBASSEMBLIES

- FIRST ORDER ANALYSIS OF RF FACTORS INFLUENCING THE OPEN LOOP ANGLE TRACKING

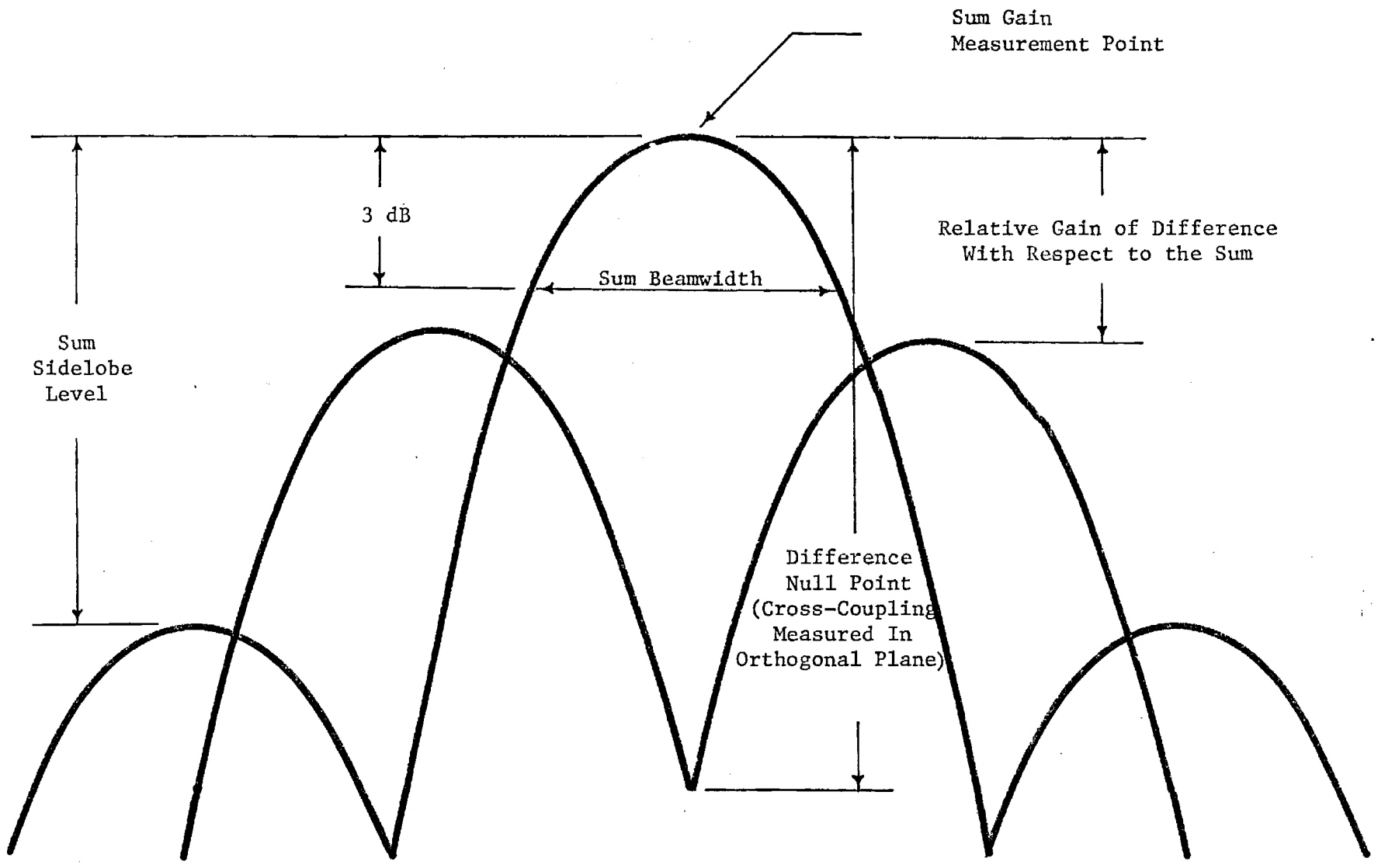
- REFURBISHMENT OF REFLECTOR/FEED ASSEMBLY

Drawings of Antenna

Front View

Side View

Top View



Principal Plane Sum and Difference Antenna Pattern Notation

SUMMARY OF TEST RESULTS

1. A SUMMARY OF ANTENNA PARAMETERS AS MEASURED ON ANTENNA #1 INCLUDES:

A. SUM GAIN

	REF LEVEL	STD GAIN LEVEL	CABLE LOSSES	NET GAIN
Σ ANTENNA	0 dB	21.5 dB	1.0 dB	22.5
Δ_{AZ}	-6 dB	15.5 dB	2.0 dB*	17.5
Δ_{EL}	-0.5 dB	21.0 dB	.2 dB	21.2
		AT RESOLVER		AT FEED

B. SUM BEAMWIDTH

AZIMUTH - 12.67 DEGREES

ELEVATION - 10.0 DEGREES

C. DIFFERENCE NULL DEPTH

AZIMUTH - >40 dB

ELEVATION - 20.6 dB

---

*INTERIM REPAIR HAS REDUCED THIS LOSS TO 0.4 dB

D. RELATIVE GAIN OF DIFFERENCE CHANNELS WITH RESPECT TO THE SUM CHANNEL

AZIMUTH - L - 6.9 dB, R - 6.0 dB (R = RIGHT SIDE, L = LEFT SIDE)

ELEVATION - L - 1.9 dB, R - 1.6 dB

E. SUM SIDELOBE LEVELS

AZIMUTH - L - 20.4 dB, R - 26.0 dB

ELEVATION - L - 15.8 dB, R - 14.6 dB

2. CROSS COUPLING LEVELS IN PLANES CLOSE TO THE DIFFERENCE NULLS. THESE PLANES WERE ORTHOGONAL TO AN AXIS OPTICALLY ESTABLISHED TO COINCIDE WITH THE GIMBAL AXES.

AZIMUTH - 28.9 dB (WORST CASE RELATIVE TO SUM GAIN)
ELEVATION - 11.8 dB (WORST CASE RELATIVE TO SUM GAIN)

THESE LEVELS COULD HAVE BEEN AS LOW AS Δ NULL LEVELS IN A PERFECTLY ALIGNED SYSTEM.

3. MAXIMUM (WORST CASE) CROSS POLARIZATION LEVELS ARE AS FOLLOWS:

$\pm$ 12° FROM BORESIGHT ($2D^2/\lambda$ RANGE)
SUM CHANNEL -42 dB
AZIMUTH DIFFERENCE -40 dB
ELEVATION DIFFERENCE -38 dB
CROSS COUPLING PLANE
AZIMUTH DIFFERENCE -36 dB
CROSS COUPLING PLANE
ELEVATION DIFFERENCE - 20dB

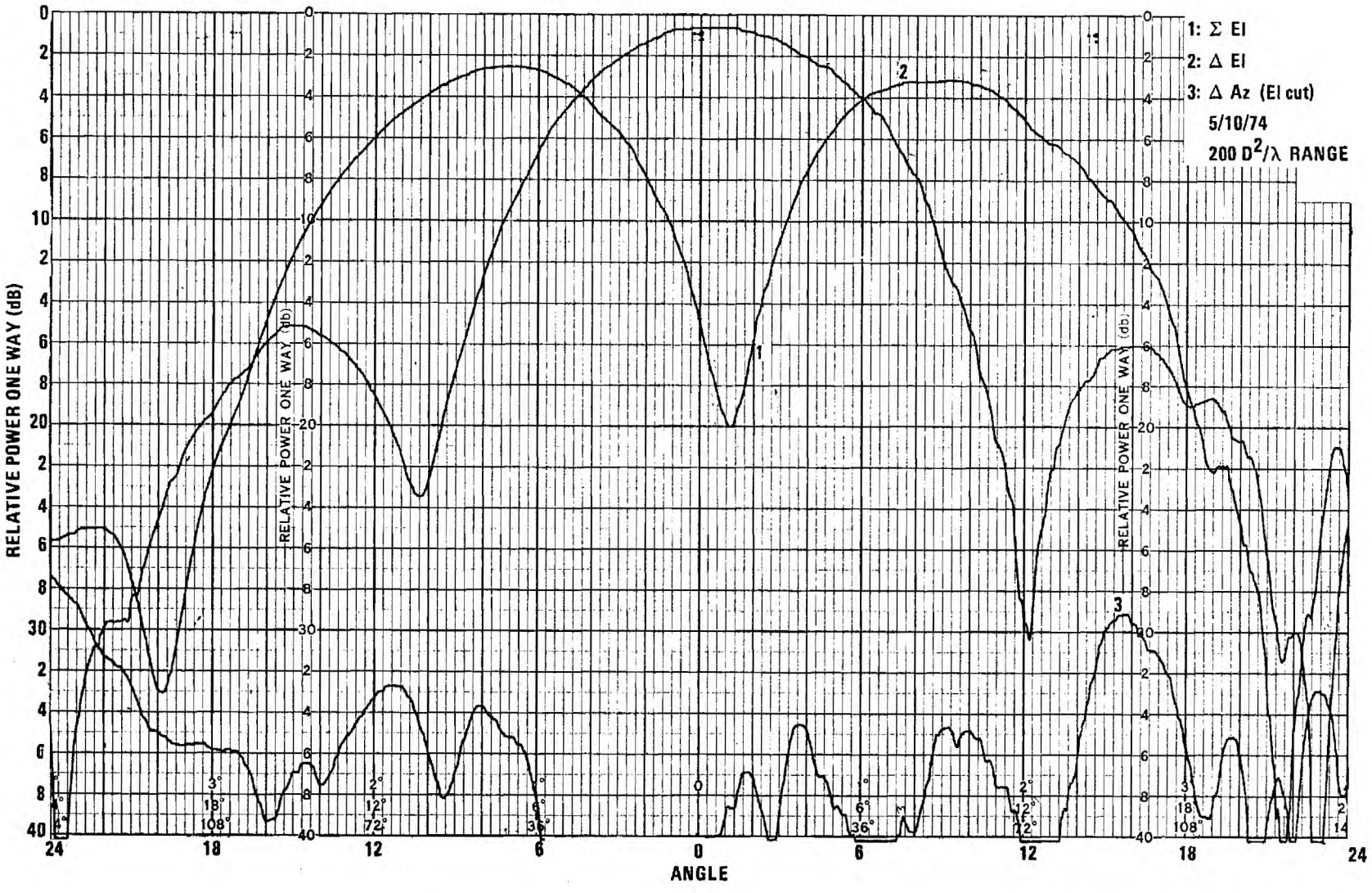
4. ON-AXIS RADOME MEASUREMENTS REVEALED THESE GENERAL RESULTS:

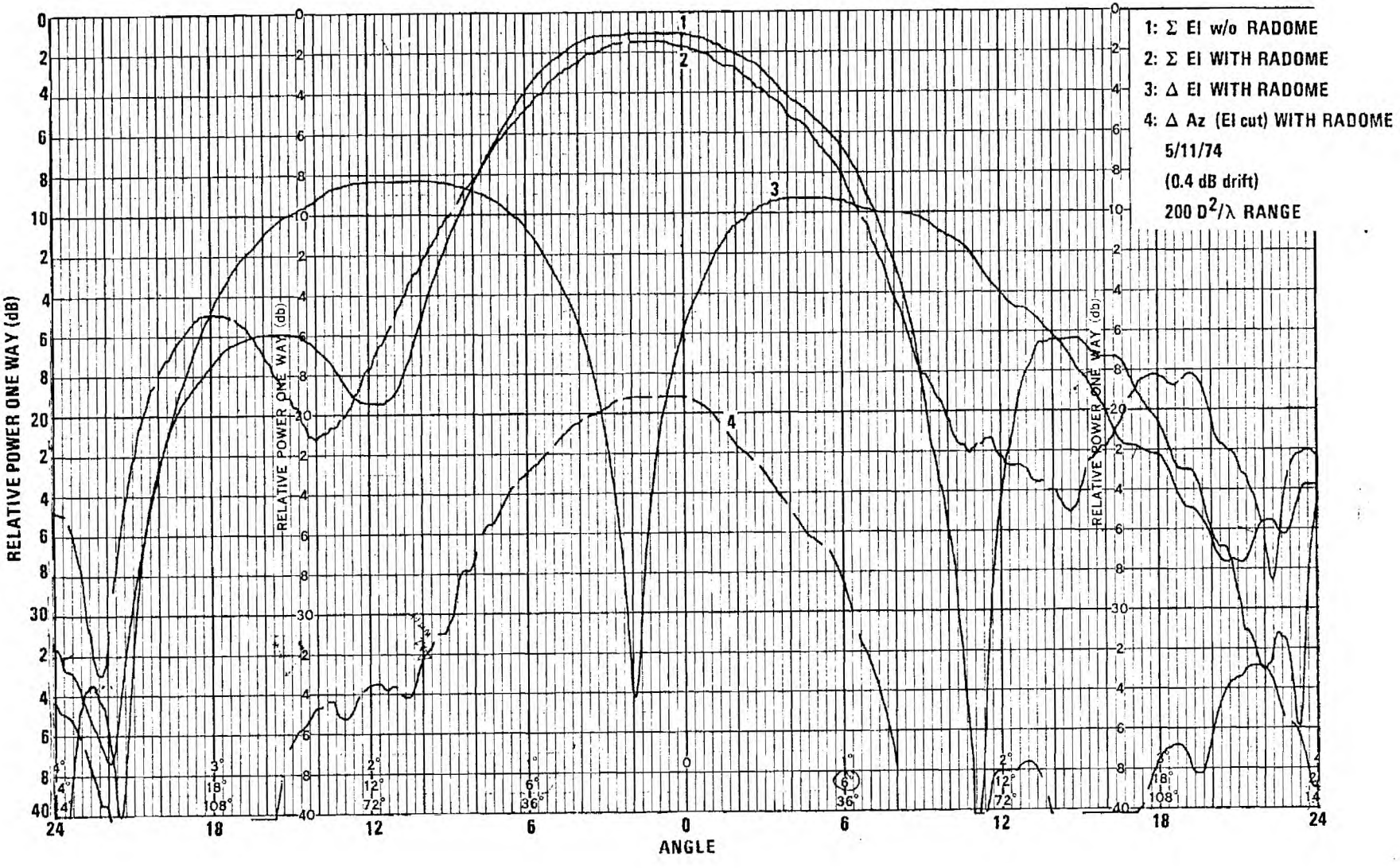
A. SUM CHANNEL GAIN LOSS 0.8 - 1.0 DB

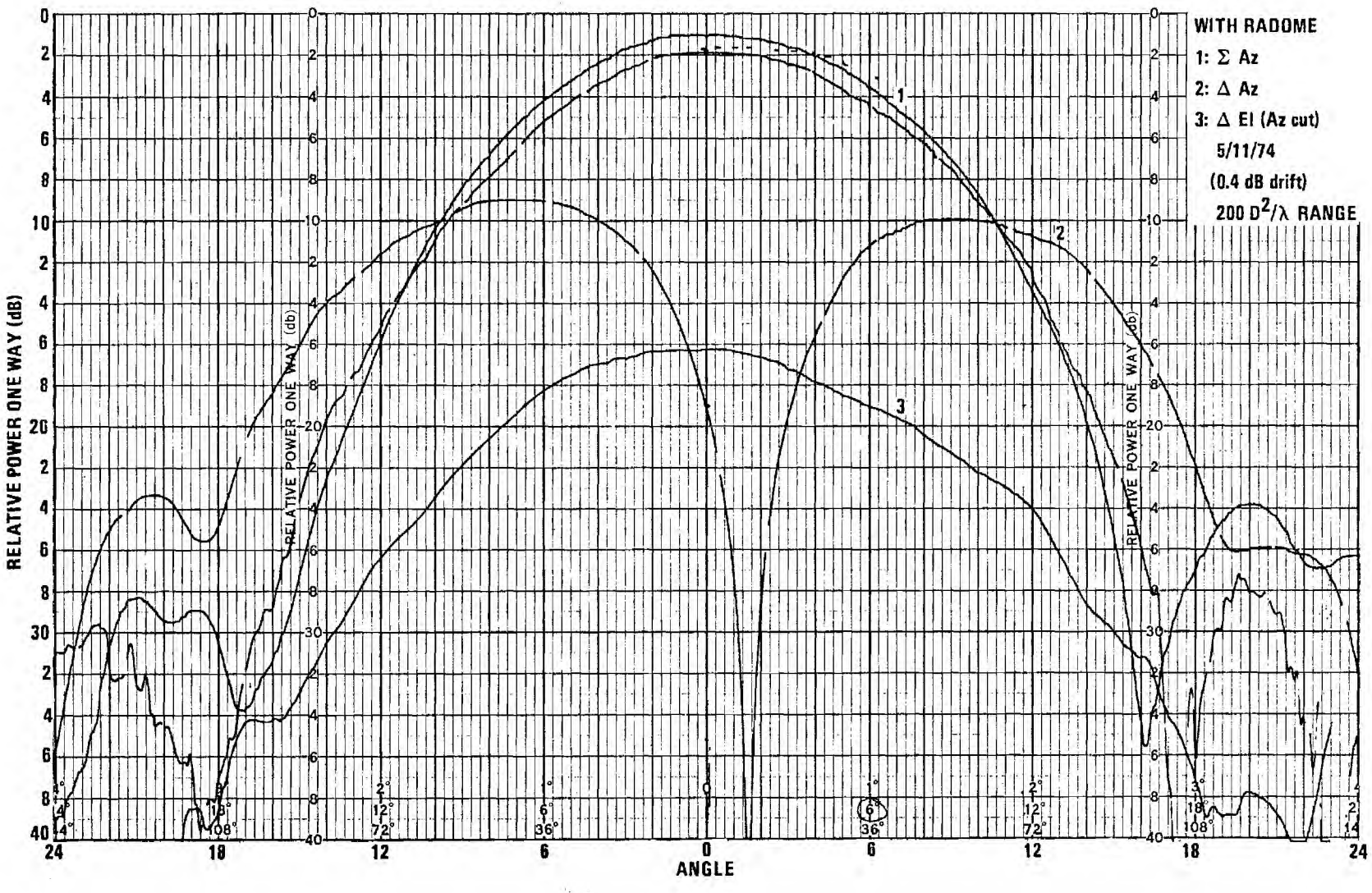
B. IMPROVEMENT OF THE ELEVATION NULL DEPTH FROM 20.6 DB TO 33.8 DB

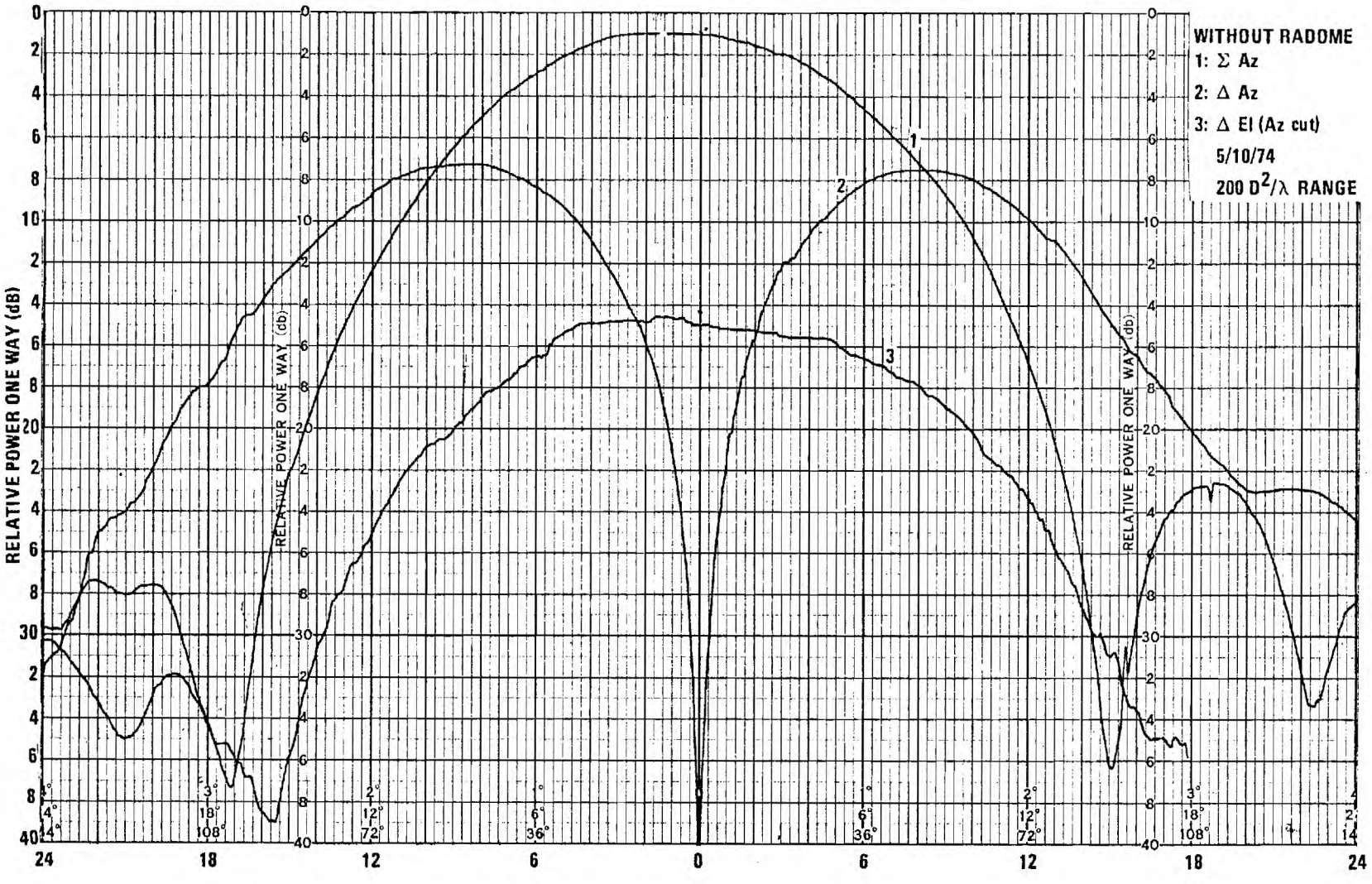
C. LOWERING OF THE RELATIVE DIFFERENCE CHANNEL GAIN AS COMPARED TO THE SUM CHANNEL

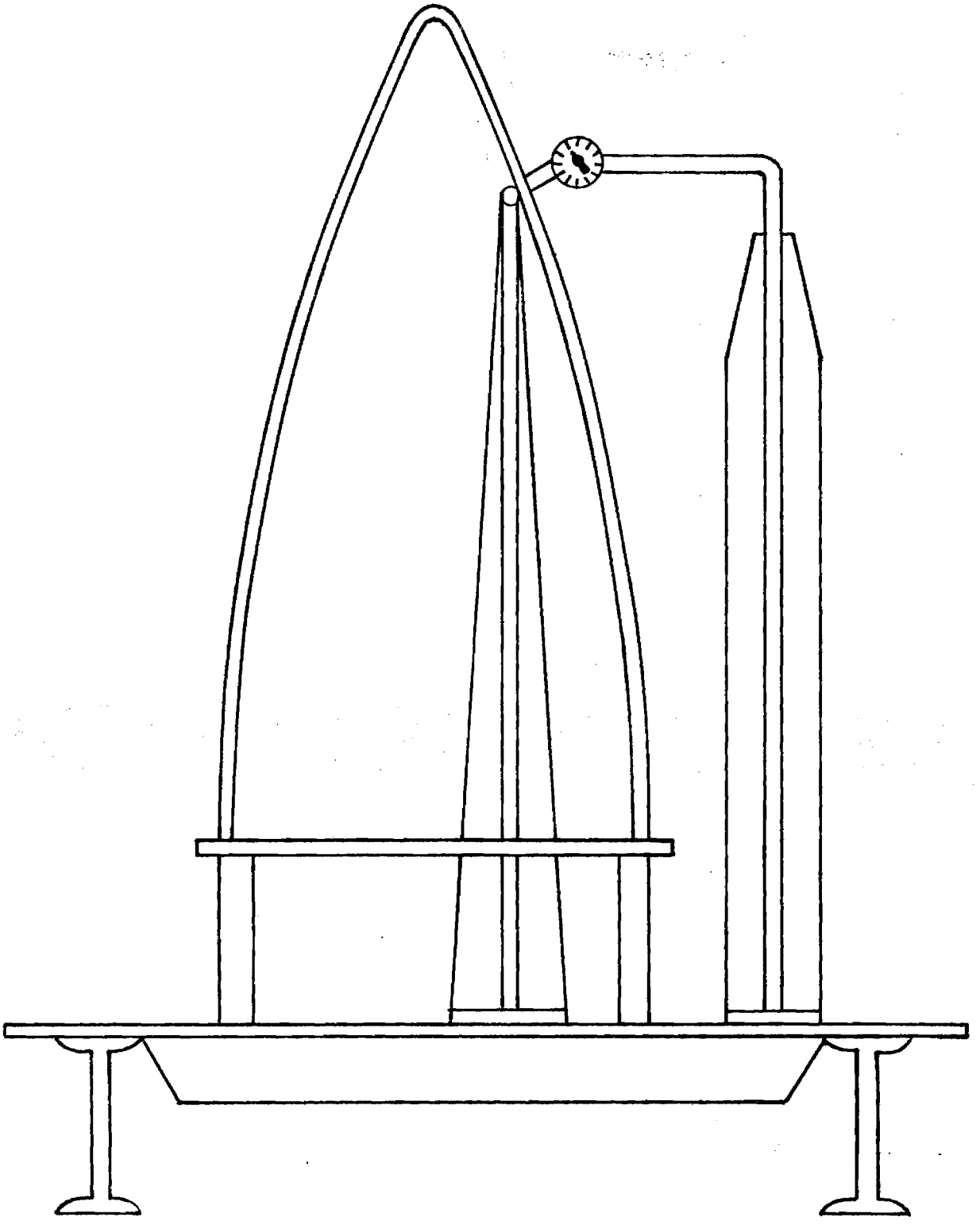
AZIMUTH - L - 8.1 DB, R - 7.1 DB
ELEVATION - L - 7.7 DB, R - 6.6 DB


1: Σ El
2: Δ El
3: Δ Az (El cut)
5/10/74
200 D²/λ RANGE
RELATIVE POWER ONE WAY (dB)
RELATIVE POWER ONE WAY (db)
ANGLE
24
18
12
6
0
6
12
18
24


1: Σ El w/o RADOME
2: Σ El WITH RADOME
3: Δ El WITH RADOME
4: Δ Az (El cut) WITH RADOME
5/11/74
(0.4 dB drift)
200 D²/λ RANGE
RELATIVE POWER ONE WAY (dB)
ANGLE


WITH RADOME
1: Σ Az
2: Δ Az
3: Δ El (Az cut)
5/11/74
(0.4 dB drift)
200 D²/λ RANGE
RELATIVE POWER ONE WAY (dB)
RELATIVE POWER ONE WAY (db)
ANGLE
24
18
12
6
0
6
12
18
24
1
2
3


WITHOUT RADOME
1: Σ Az
2: Δ Az
3: Δ El (Az cut)
5/10/74
200 D²/λ RANGE
RELATIVE POWER ONE WAY (dB)
RELATIVE POWER ONE WAY (db)
RELATIVE POWER ONE WAY (db)
1
2
3
24
18
12
6
0
6
12
18
24



Apparatus Used to Measure Wall Thickness of Radome Shapes.

Drawing of Radome

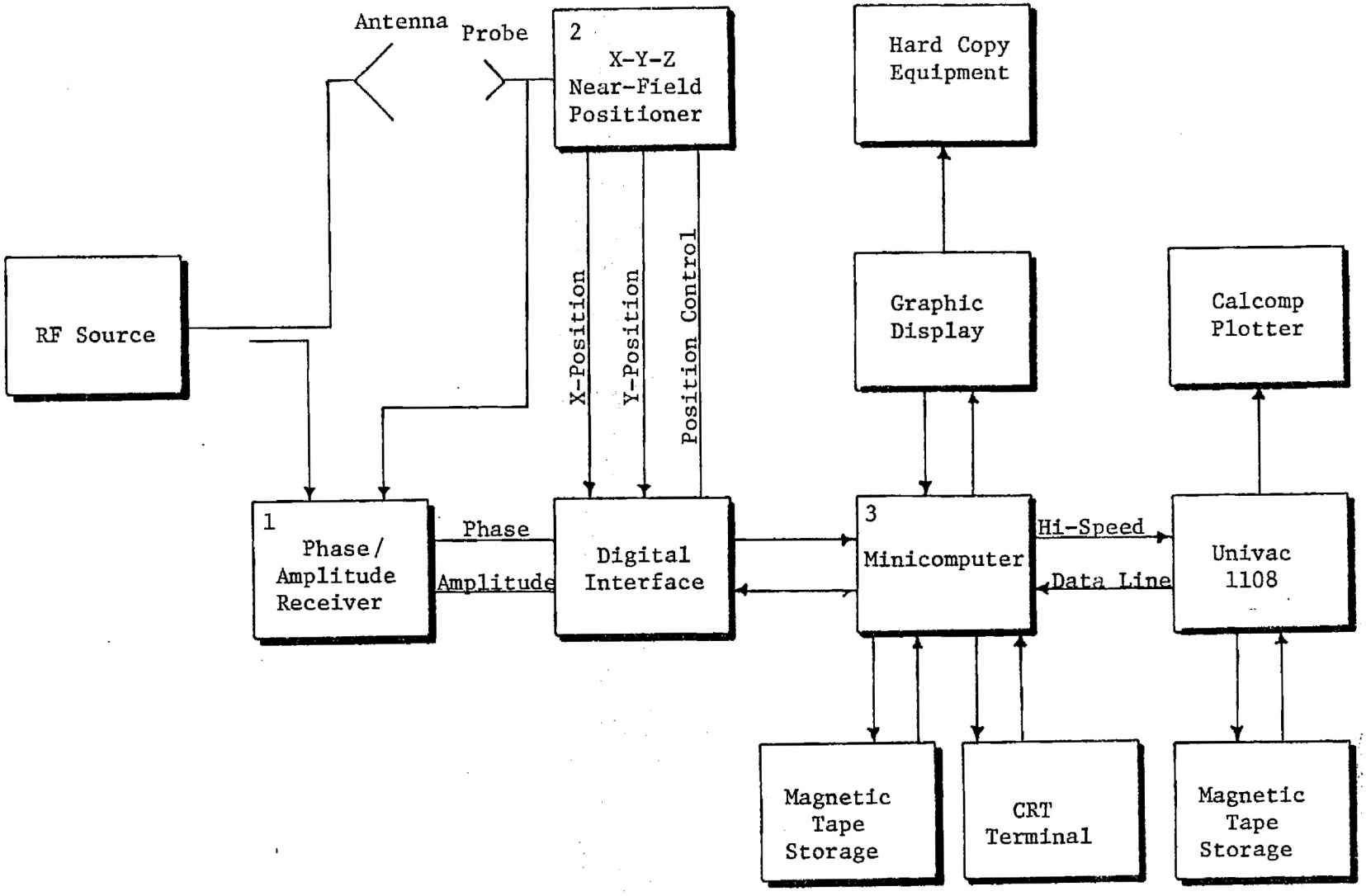
RADOME CHARACTERISTICS SUMMARY

SHAPE	TANGENT OGIVE FROM BASE TO APPROXIMATELY 14 INCHES FROM TIP. SIMPLE CONE FROM THIS POINT FORWARD (14.5° CONE ANGLE).
BASE DIAMETER	12.985 INCHES
WALL THICKNESS	0.175-0.200-INCH FOR 3 INCHES ABOVE BASE OF RADOME. 0.400-INCH OVER REST OF RADOME.
RADOME FABRICATION	FIBERGLAS FORMED BY MATCH MOLDING A KNITTED OR WOVEN SOCK THAT HAS BEEN STITCHED IN SEVERAL PLACES.
TIP	METAL TIP (STAINLESS STEEL), 2.45 INCHES LONG.

$$T_W = \frac{N \lambda_0}{2\sqrt{\epsilon_R - \sin^2 \theta_D}} = 0.416 \text{ INCHES}$$

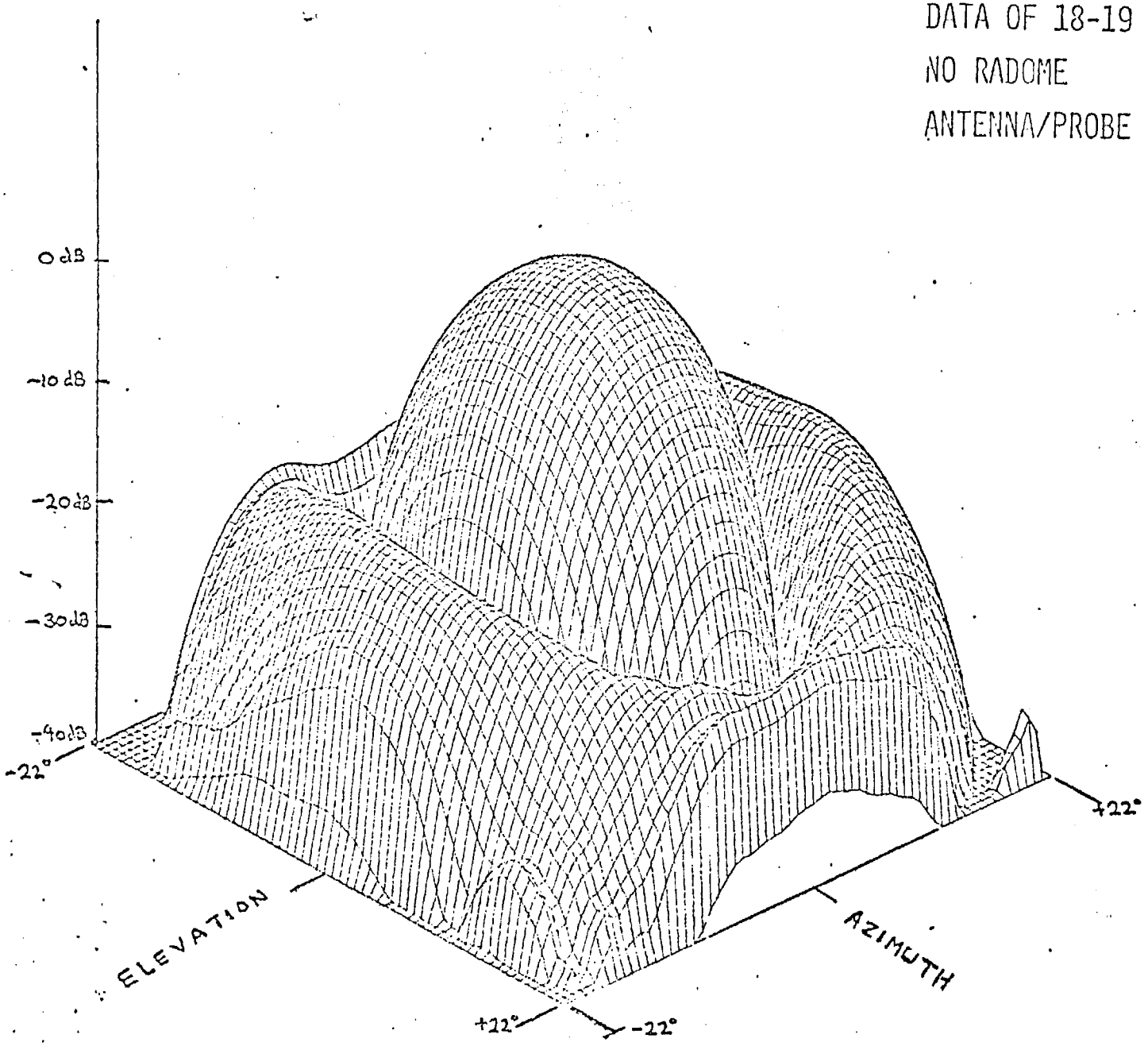
$$\epsilon_R = 4.8$$

AND θ_D, (DESIGN ANGLE OF INCIDENCE) = 55°

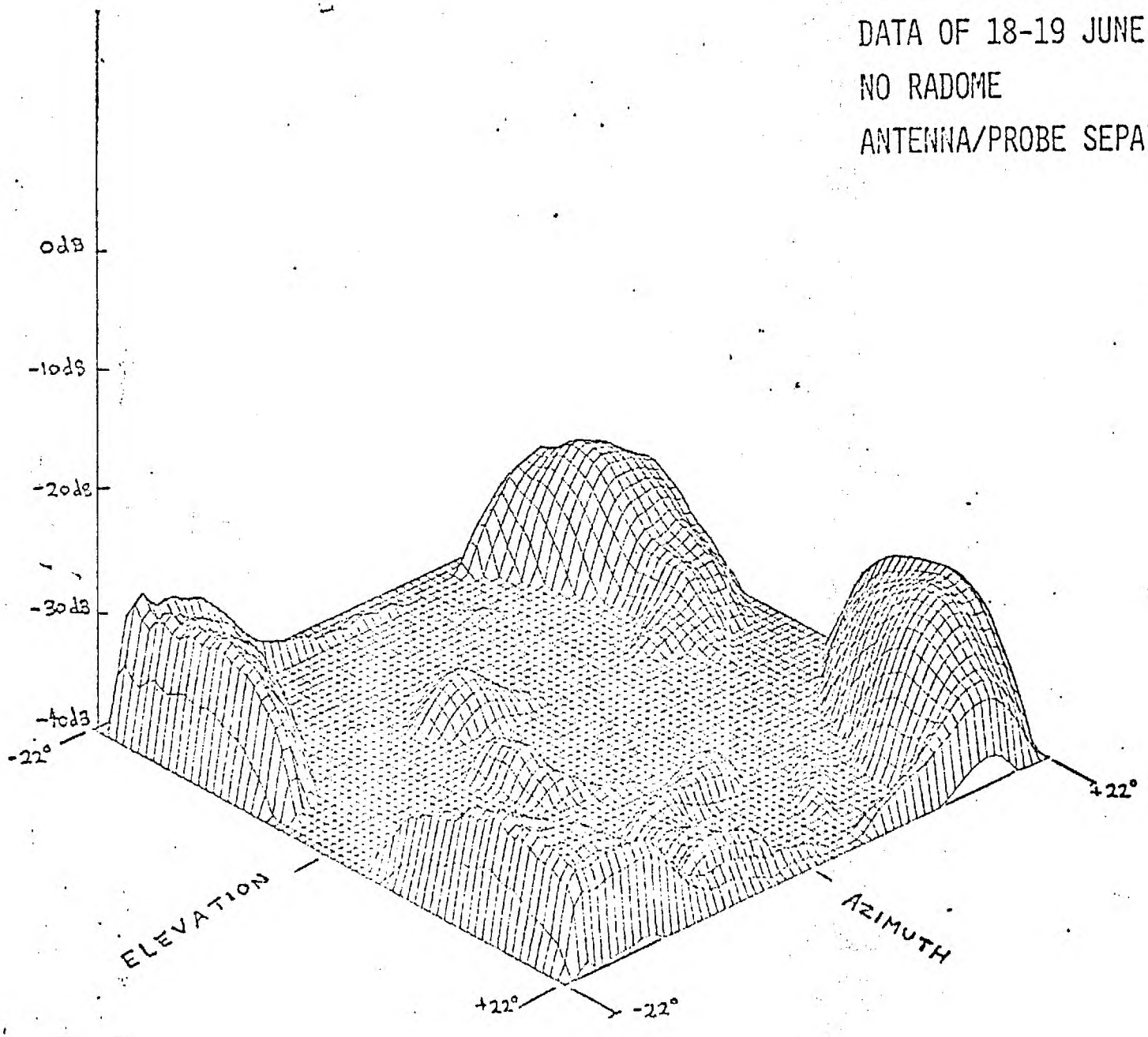


Block Diagram of Automated Near-Field Facility and Computer Link

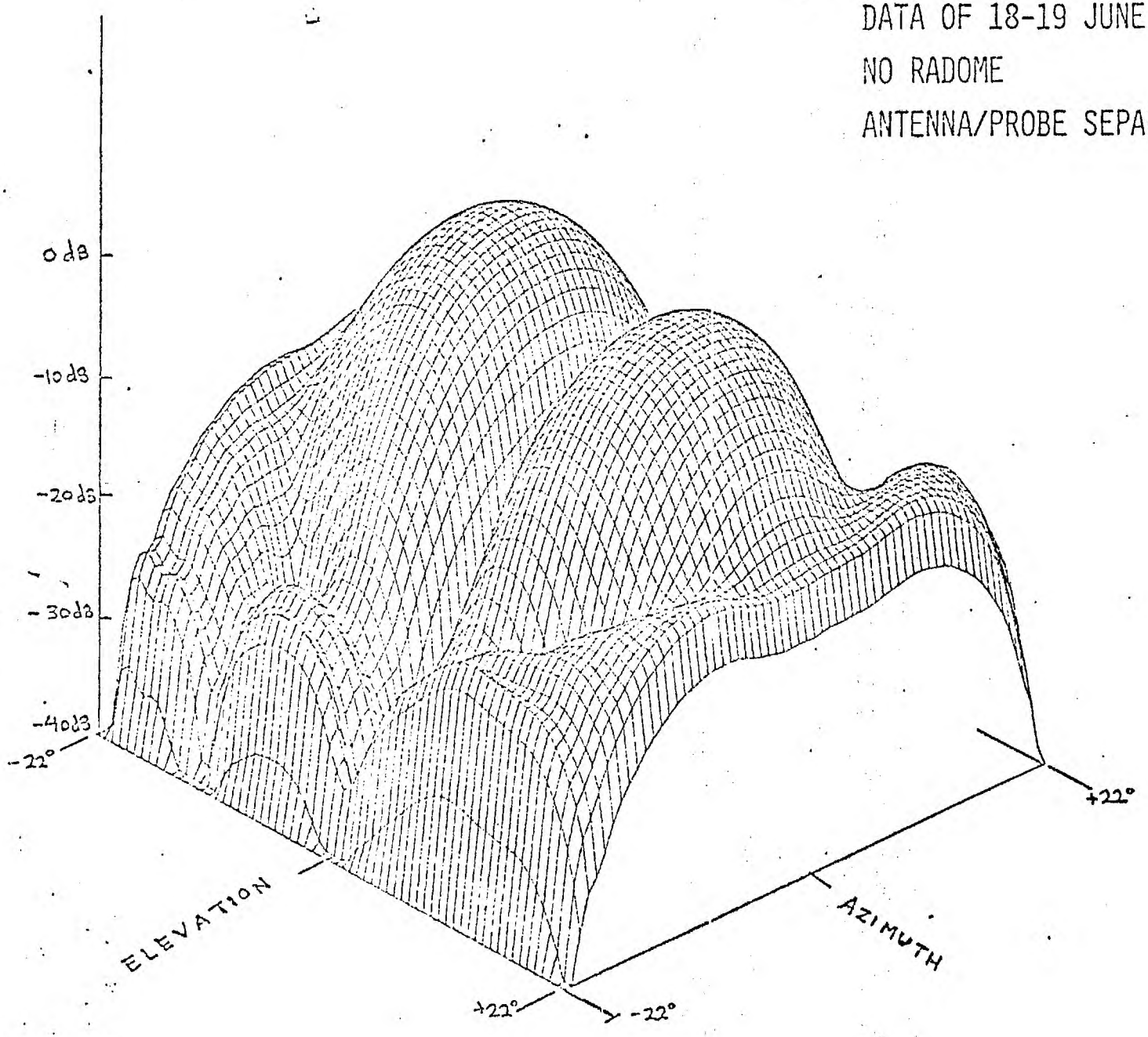
PARALLEL POLARIZATION
DATA OF 18-19 JUNE 1974
NO RADOME
ANTENNA/PROBE SEPARATION 2λ



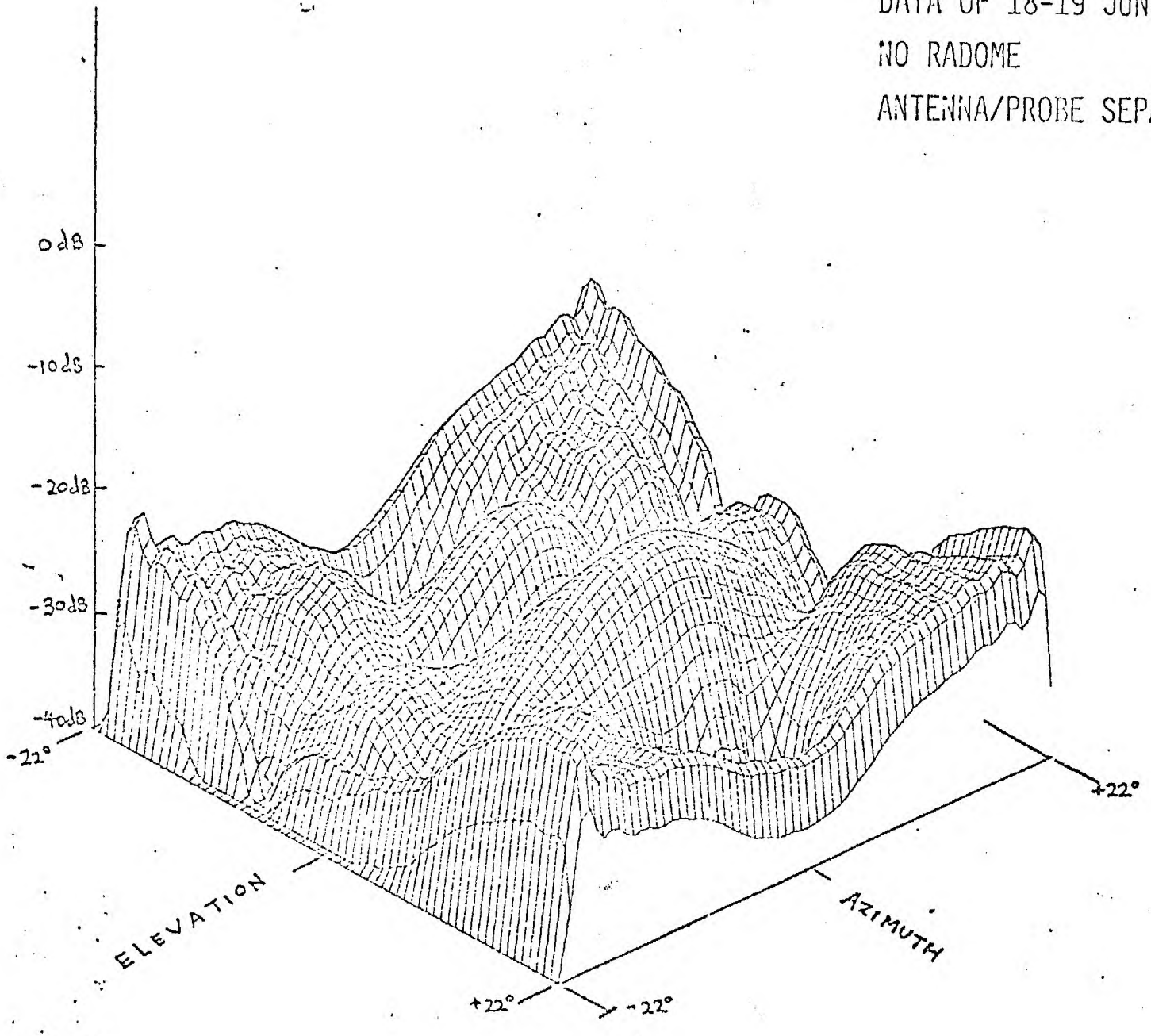
CROSS POLARIZATION
DATA OF 18-19 JUNE 1974
NO RADOME
ANTENNA/PROBE SEPARATION 2 λ



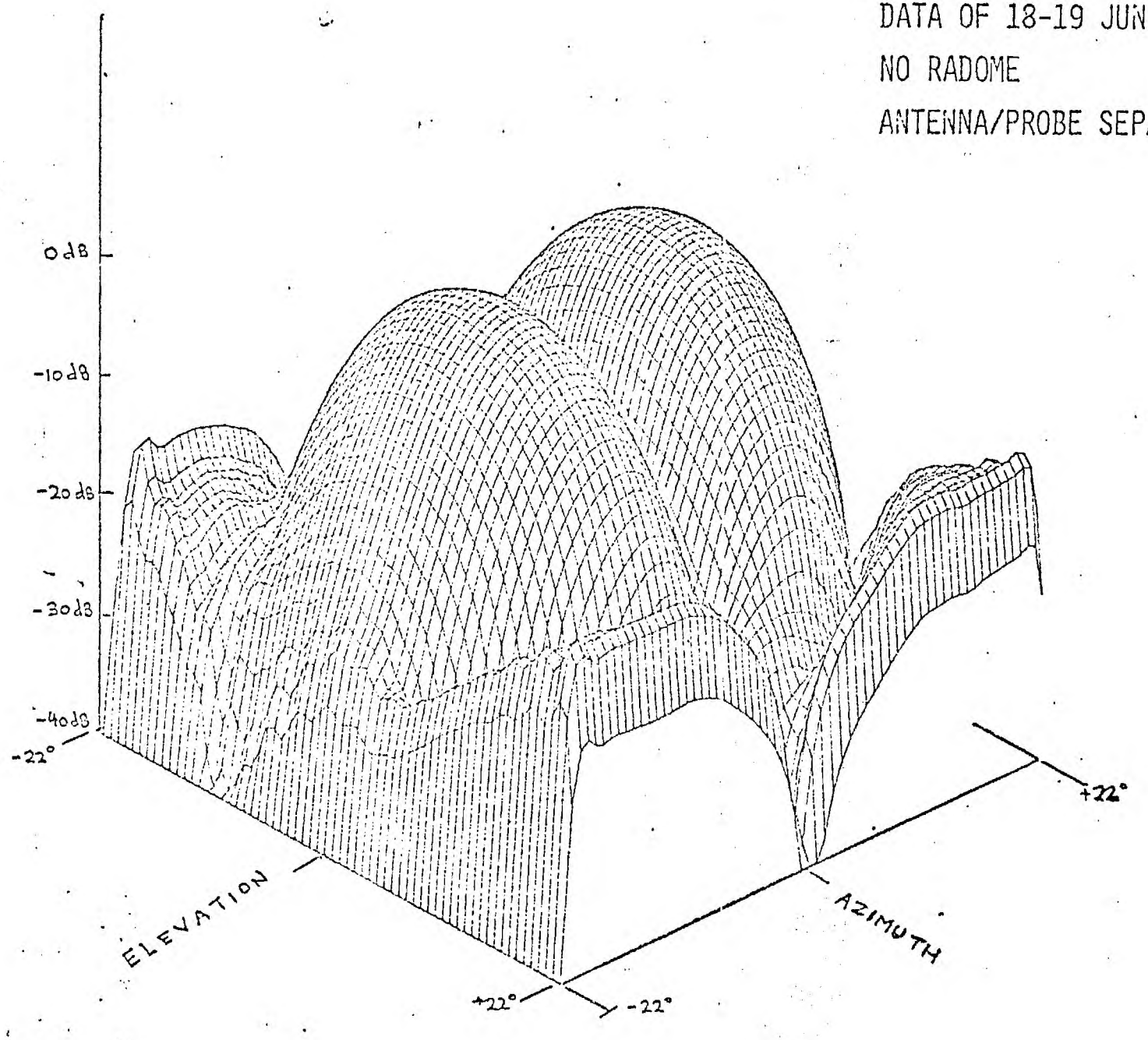
PARALLEL POLARIZATION
DATA OF 18-19 JUNE 1974
NO RADOME
ANTENNA/PROBE SEPARATION 2λ



CROSS POLARIZATION
DATA OF 18-19 JUNE 1974
NO RADOME
ANTENNA/PROBE SEPARATION 2λ



PARALLEL POLARIZATION
DATA OF 18-19 JUNE 1974
NO RADOME
ANTENNA/PROBE SEPARATION 2λ

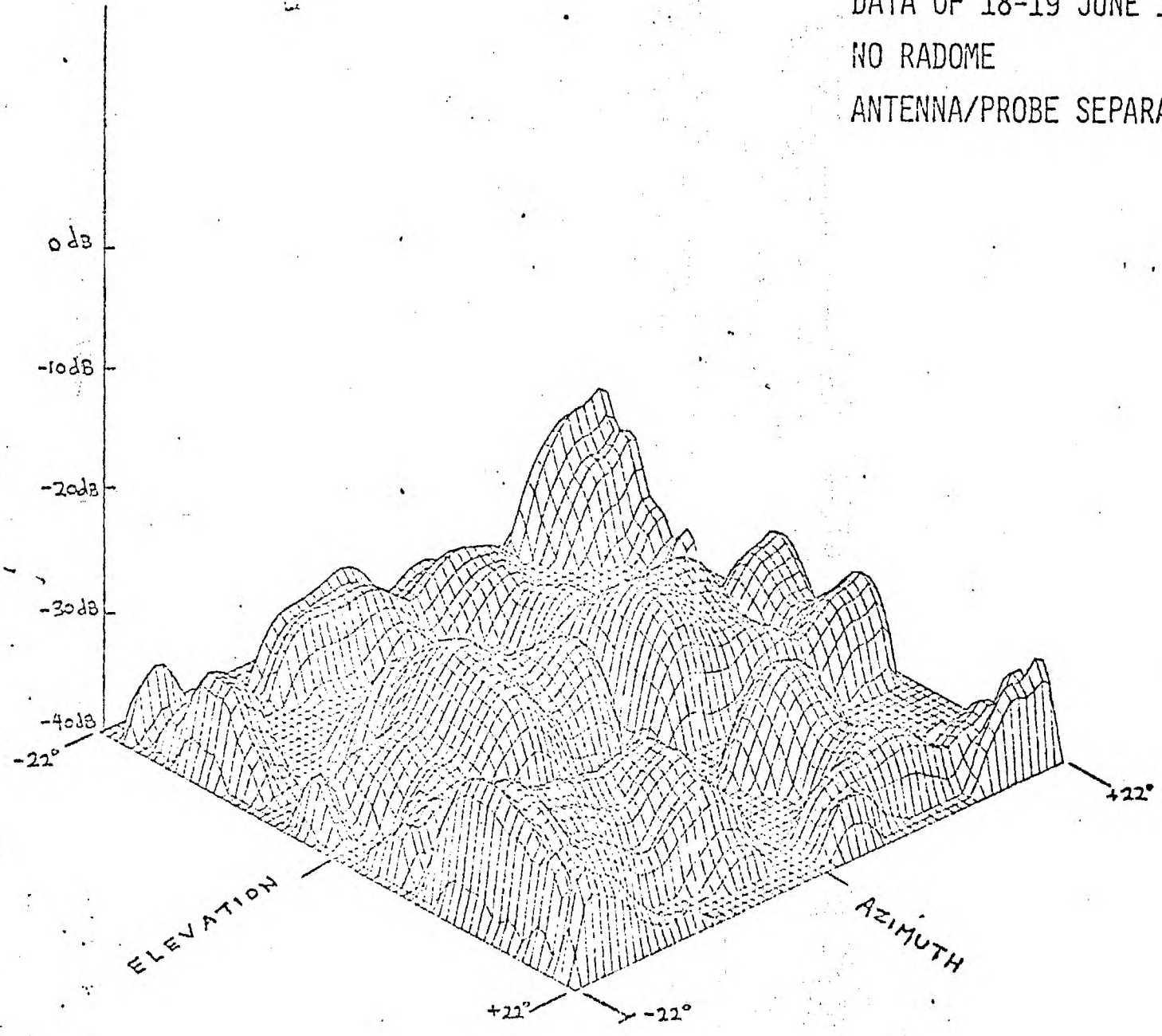


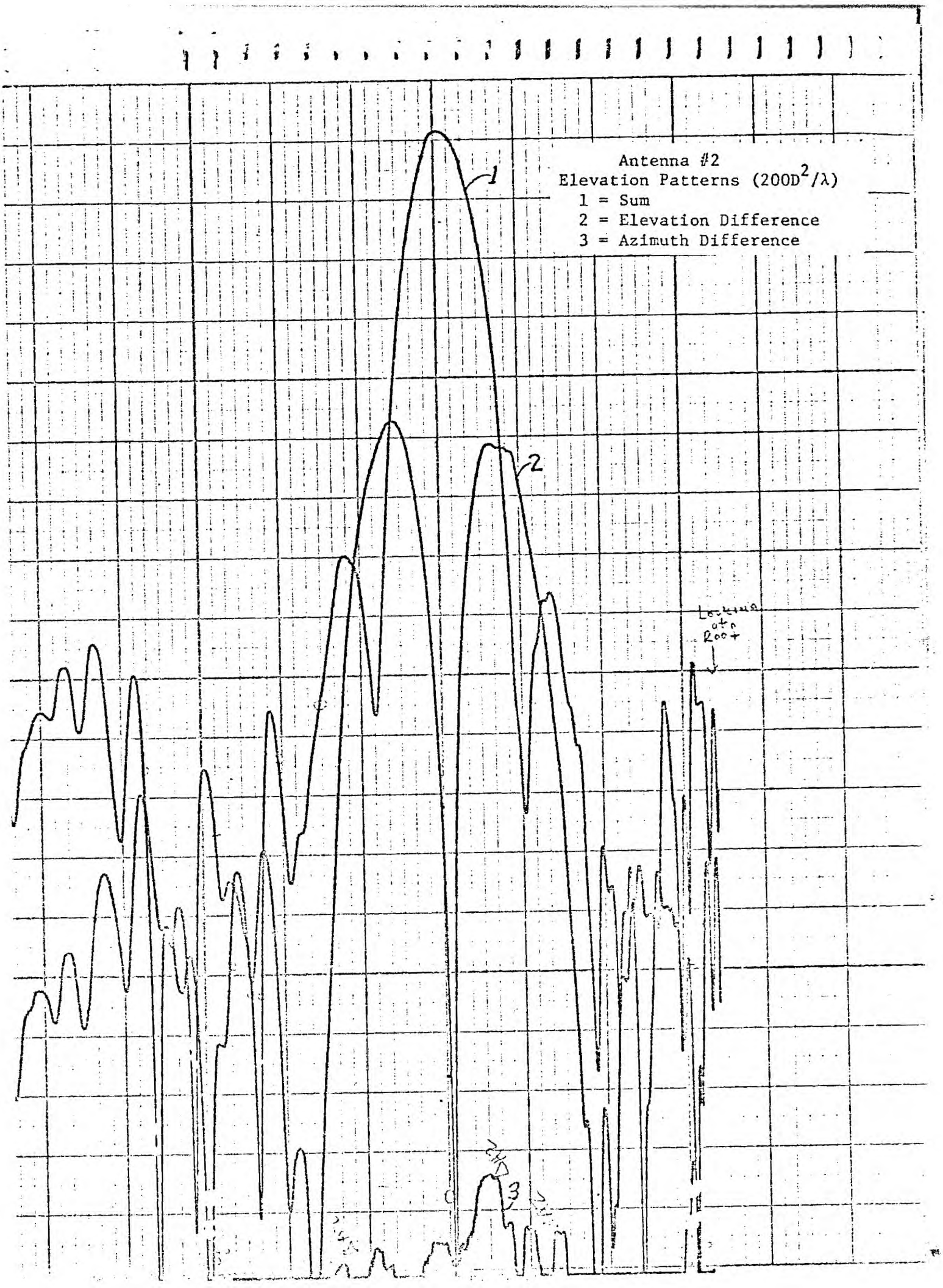
CROSS POLARIZATION

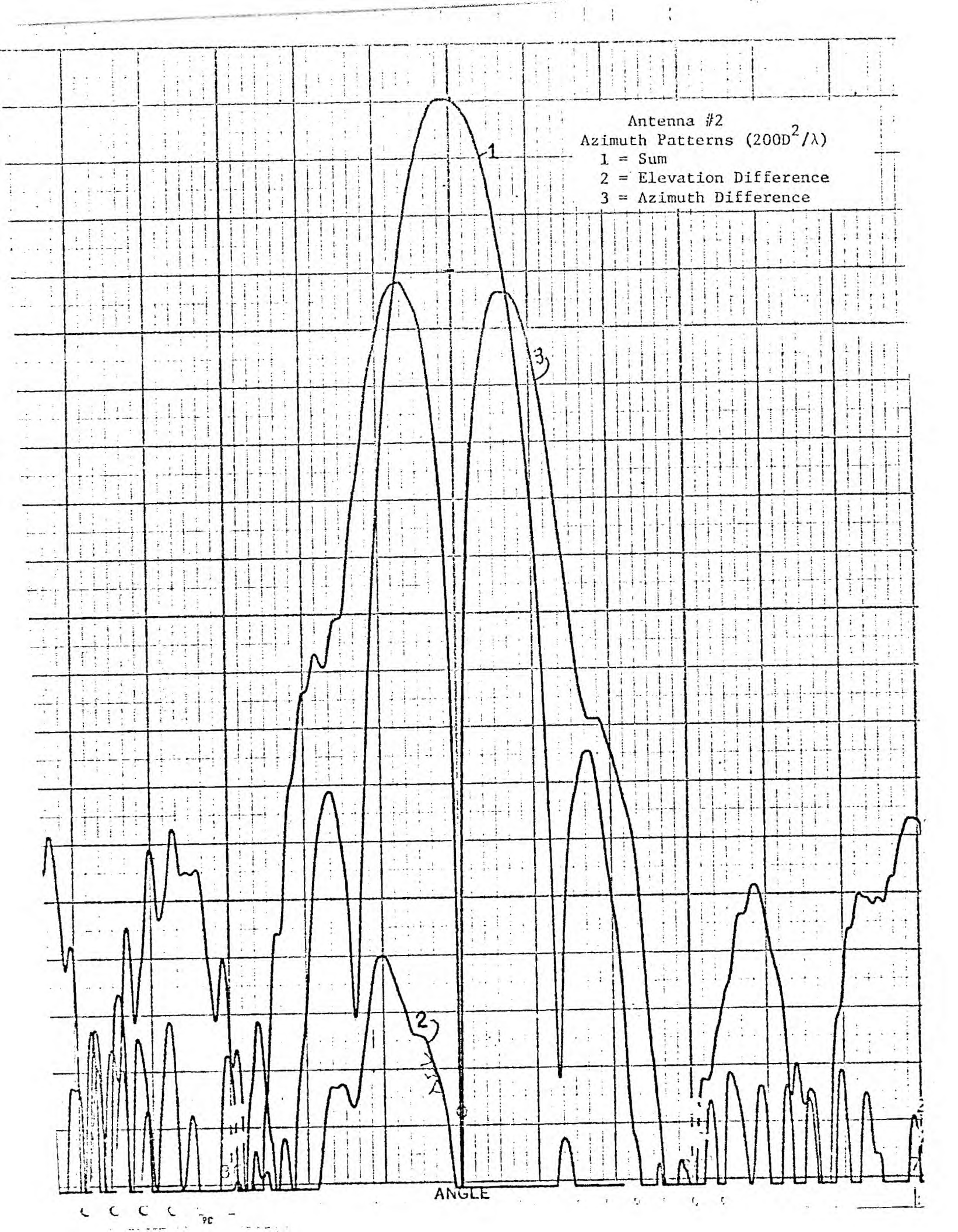
DATA OF 18-19 JUNE 1974

NO RADOME

ANTENNA/PROBE SEPARATION 2 λ




Antenna #2
Elevation Patterns (200D²/λ)
1 = Sum
2 = Elevation Difference
3 = Azimuth Difference
1
2
3
Locking
onto
Roof


Antenna #2
Azimuth Patterns (200D²/λ)
1 = Sum
2 = Elevation Difference
3 = Azimuth Difference
1
2
3
ANGLE

5. THE FOLLOWING ANTENNA PARAMETERS WERE MEASURED ON ANTENNA #2:

A. SUM BEAMWIDTH

AZIMUTH - 12 DEGREES
ELEVATION - 9.5 DEGREES

B. DIFFERENCE NULL DEPTH

AZIMUTH - >40 dB
ELEVATION - >40 dB

C. RELATIVE GAIN OF DIFFERENCE CHANNELS (HERE CABLE EFFECTS ARE INCLUDED)

AZIMUTH - R - 6.8 dB, L - 6.5 dB
ELEVATION - R - 10.5 dB, L - 9.8 dB

EFFECT OF POLARIZATION GRID

PURPOSE

TO REDUCE THE EFFECT OF CROSSPOLARIZATION ON DIRECTION FINDING ACCURACY.

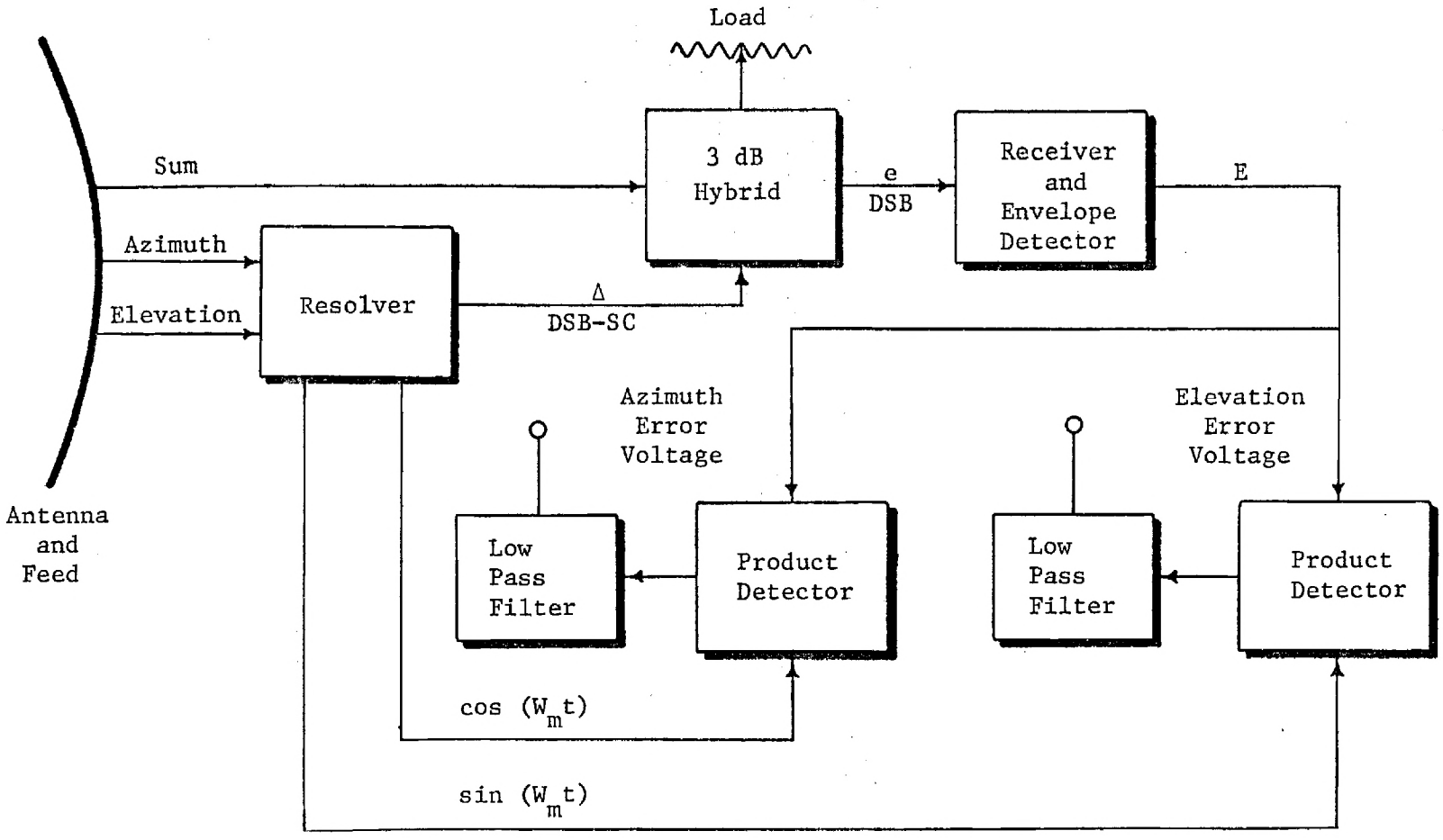
AMOUNT*

$$T_0 \cong \frac{1}{1 + \left[\frac{\lambda}{2S} \cdot \frac{1}{\ell n(2\pi R_0/S)}\right]^2}$$

CALCULATED: 10 LOG T_0 = 13.7 dB

MEASURED ($\pm$ 12° SECTOR NEAR BORESIGHT) (2 LAYERS) 14 dB MAX

*MONOPULSE RADAR, A. LEONEV & K. I. FOMICHEV, MOSCOW 1970.



Block Diagram of a Conical - Scan-on-Receive Angle Tracking System

ANGLE TRACKER ANALYSIS

PURPOSE

To be to assess the effects of RF Phase Errors, Resolver Imperfections and Receiver caused errors on the Angle Tracker Output.

OF INTEREST FOR TWO REASONS

- Understanding Data Already Taken
- Provide Design Information for Future Work

IDEALIZED ANGLE TRACKER EQUATIONS

ANTENNA OUTPUTS

$$AZ = K_A F_A(\theta,\Phi)\ \cos(\omega_r t)$$

$$EL = K_E F_E(\theta,\Phi)\ \cos(\omega_r t)$$

$$SUM = K_S F_S(\theta,\Phi)\ \cos(\omega_r t)$$

RESOLVER OUTPUT = Δ

$$\Delta = K_A F_A \cos(\omega_m t) + K_E F_E \sin(\omega_m t)$$

HYBRID OUTPUT = e

$$e = K_S F_S - K_A F_A \cos(\omega_m t) - K_E F_E \sin(\omega_m t)$$

CAN BE PUT IN THIS FORM:

$$= \left[1 + M\ F(\omega_m t)\right] \cos(\omega_r t)$$

DEFINE $1 + M\ F(\omega_m t)$ AS THE ENVELOPE

RECEIVER OUTPUT = E

$$E = \text{ENVELOPE} - 1 = M\,F(\omega_m t)$$

$$E = (K_S F_S - 1) - K_A F_A \cos(\omega_m t) - K_E F_E \sin(\omega_m t)$$

ERROR VOLTAGE

$$\text{AZIMUTH} = E \cdot \cos(\omega_m t)$$

$$\text{AZIMUTH} = -1/2\ K_A F_A\ (\theta, \phi)$$

$$\text{ELEVATION} = E \cdot \sin(\omega_m t)$$

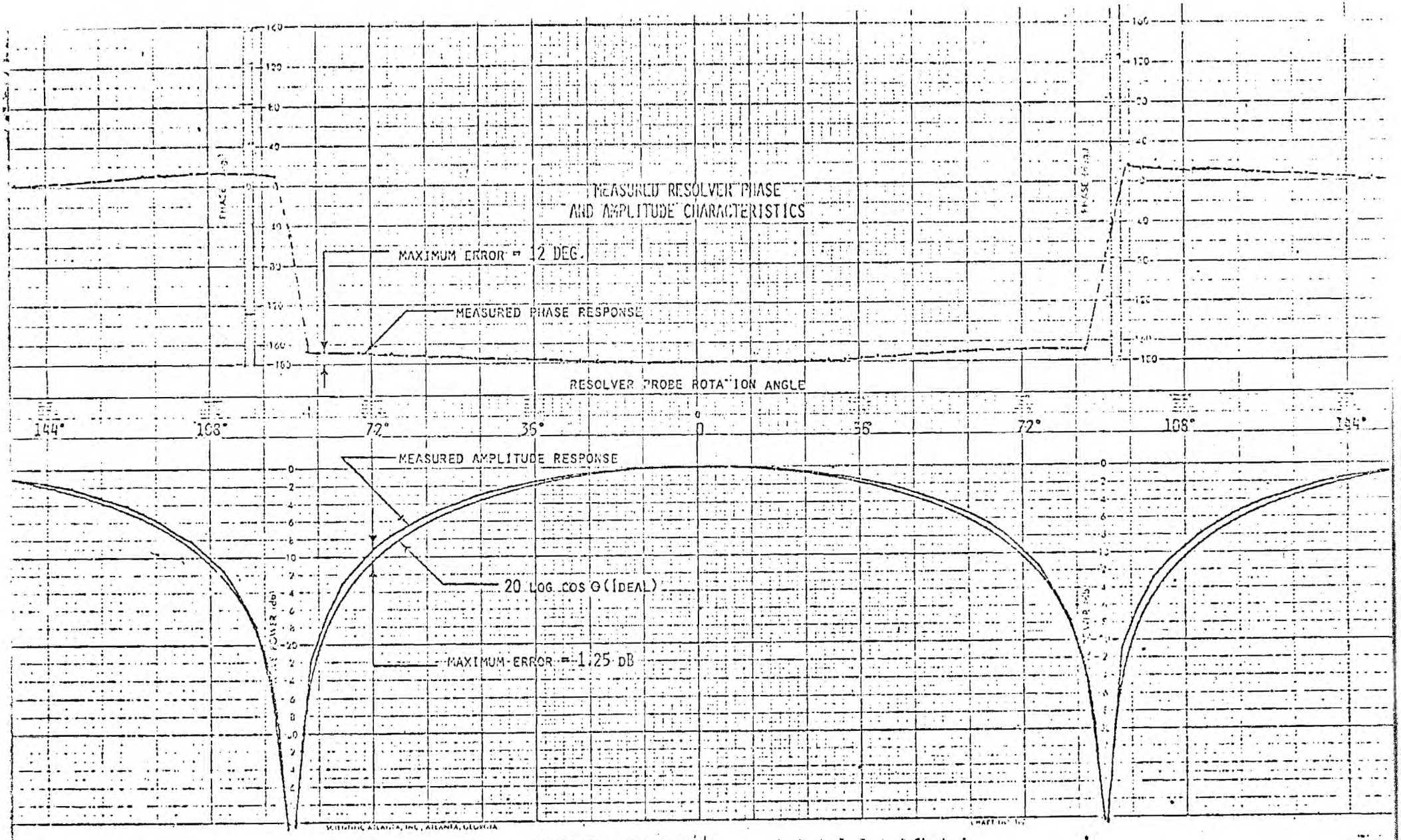
$$\text{ELEVATION} = -1/2\ K_E F_E\ (\theta, \phi)$$

IN THE GENERAL CASE WE HAVE INCLUDED OTHER FACTORS

- RF Phase Shifts Other Than Zero
- Mutual Coupling in Antenna and Hybrid
- Resolver Non Orthogonality

WE OUTPUT

- Envelope Detector
  (Provides Contours of Constant Amplitude and Phase)
- AZ and EL Error Voltages


MEASURED RESOLVER PHASE
AND AMPLITUDE CHARACTERISTICS
MAXIMUM ERROR = 12 DEG.
MEASURED PHASE RESPONSE
RESOLVER PROBE ROTATION ANGLE
144°
108°
72°
36°
0
36
72°
108°
144°
MEASURED AMPLITUDE RESPONSE
20 LOG COS θ (IDEAL)
MAXIMUM ERROR = 1.25 dB

FUTURE EFFORTS

1. CONTINUE REFURBISHMENT, XRAY SELECTED ASSEMBLIES AND DOCUMENTATION ACTIVITIES

2. PERFORM EXTENSIVE POST REFURBISHMENT RF MEASUREMENTS

   A. Antenna Feed
      - Patterns
      - VSWR and Isolation VS FREQ

   B. Assembled Antenna

   C. Assembled Resolver
      - Phase, Amplitude
      - VSWR vs FREQ

3. EXERCISE ANGLE TRACKER MATH MODEL ON THE COMPUTER

4. ELECTRONICS MEASUREMENT PROGRAM

5. INTERIM AND FINAL REPORTS

ELECTRONICS MEASUREMENTS

- Local Oscillator Evaluation
- System Noise Figure
- Detailed Power Supply Investigation
- Measurements on Selected Servo Subsystems

OTHER POSSIBLE ACTIVITY AREAS INCLUDE

- Limited Environmental Testing
- Tolerance Study

Drawings of Resolver

End View

Side View

SUPPLEMENTARY DATA

IDEAL ANGLE TRACKER SYSTEM OPERATION

I. Received Signal as a function of spatial position

Azimuth = $K_1F_1\ (r,\theta,\Phi)$

Elevation = $K_2F_2\ (r,\theta,\Phi)$

Sum = $K_3F_3(r,\theta,\Phi)$

II. Resolver output

$$\Delta = K_1F_1(r,\theta,\Phi)\ \text{Cos}\ (\omega_m t) + K_2F_2(r,\theta,\Phi)\ \text{Sin}\ (\omega_m t)$$

(a) orthogonality of waveguide signals assumed

(b) RF phase shifts are ignored

(c) ω_m is the resolver probe frequency

III. 3 dB hybrid coupler

$$e = [K_3F_3 - K_1F_1\ \text{Cos}\ (\omega_m t) - K_2F_2\ \text{Sin}\ (\omega_m t)]$$

(a) a & b above apply

(b) difference output used

(c) This is a DSB (Convention AM) signal of the form

$$e = [k + mf(\omega_m t)]\ \cos\ (\omega_r t)$$

IV. Conventional envelope detection produces

$$E = (K_3F_3 - k) - K_1F_1\ \cos\ (\omega_m t) - K_2F_2\ \sin\ (\omega_m t)$$

No carrier present at this time.

V. Employing product (coherent) detection, the azimuth and elevation error signal are

$$\text{Azimuth error} = -\tfrac{1}{2} K_1 F_1 (r,\theta,\Phi)$$

$$\text{Elevation error} = -\tfrac{1}{2} K_2 F_2 (r,\theta,\Phi)$$

The coherent reference signals are generated by the resolver reference generator.

VI. Allowing non-ideal operation of the antenna/resolver assembly, the signal present at the receiver is

$$e = \sqrt{A^2 + B^2} \sin (\omega_r t + \hat{\Phi})$$

where

$$\hat{\Phi} = \tan^{-1} [A/B]$$

ω_r = signal frequency

$$A = K_3 F_3(r,\theta,\bar{\Phi}) \cos (\bar{\Phi}_3) - K_1 F_1(r,\theta,\Phi) \cos (\bar{\Phi}_1) \cos (\omega_m t)$$

$$- K_2 F_2(r,\theta,\bar{\Phi}) \cos (\bar{\Phi}_2) \cos (\psi) \cos (\omega_m t)$$

$$- K_2 F_2(r,\theta,\bar{\Phi}) \cos (\bar{\Phi}_2) \sin (\psi) \sin (\omega_m t)$$

$$B = - K_3 F_3(r,\theta,\bar{\Phi}) \sin (\bar{\Phi}_3)$$

$$+ K_1 F_1(r,\theta,\bar{\Phi}) \sin (\bar{\Phi}_1) \cos (\omega_m t)$$

$$+ K_2 F_2(r,\theta,\bar{\Phi}) \sin (\bar{\Phi}_2) \cos (\psi) \cos (\omega_m t)$$

$$+ K_2 F_3(r,\theta,\bar{\Phi}) \sin (\bar{\Phi}_2) \sin (\psi) \sin (\omega_m t)$$

ψ = spatial angle between azimuth and elevation signals in resolver

$\bar{\Phi}_1, \bar{\Phi}_2, \bar{\Phi}_3$ = RF phase shifts

Preliminary Test Data

Summary on the Passive Microwave Equipment and Downconversion

MISSILE RF SYSTEMS INVESTIGATION

11 December 1974

Contract DAAH01-74-C-0743
(A-1622)

J. M. Schuchardt
J. M. Newton

Systems and Techniques Department
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

PASSIVE MICROWAVE EQUIPMENT TEST DATA

I. Resolver

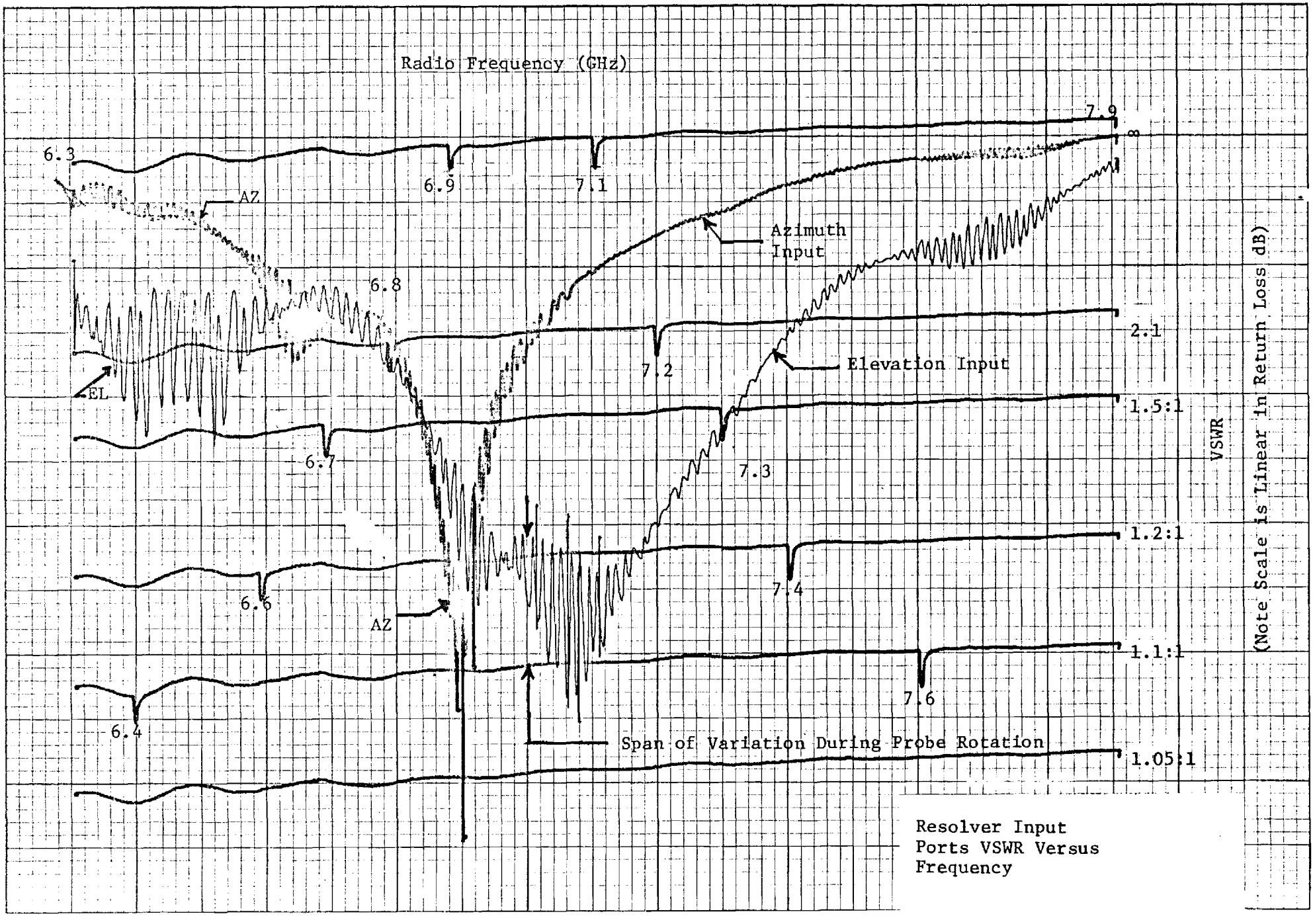
II. Hybrid

III. Mixer

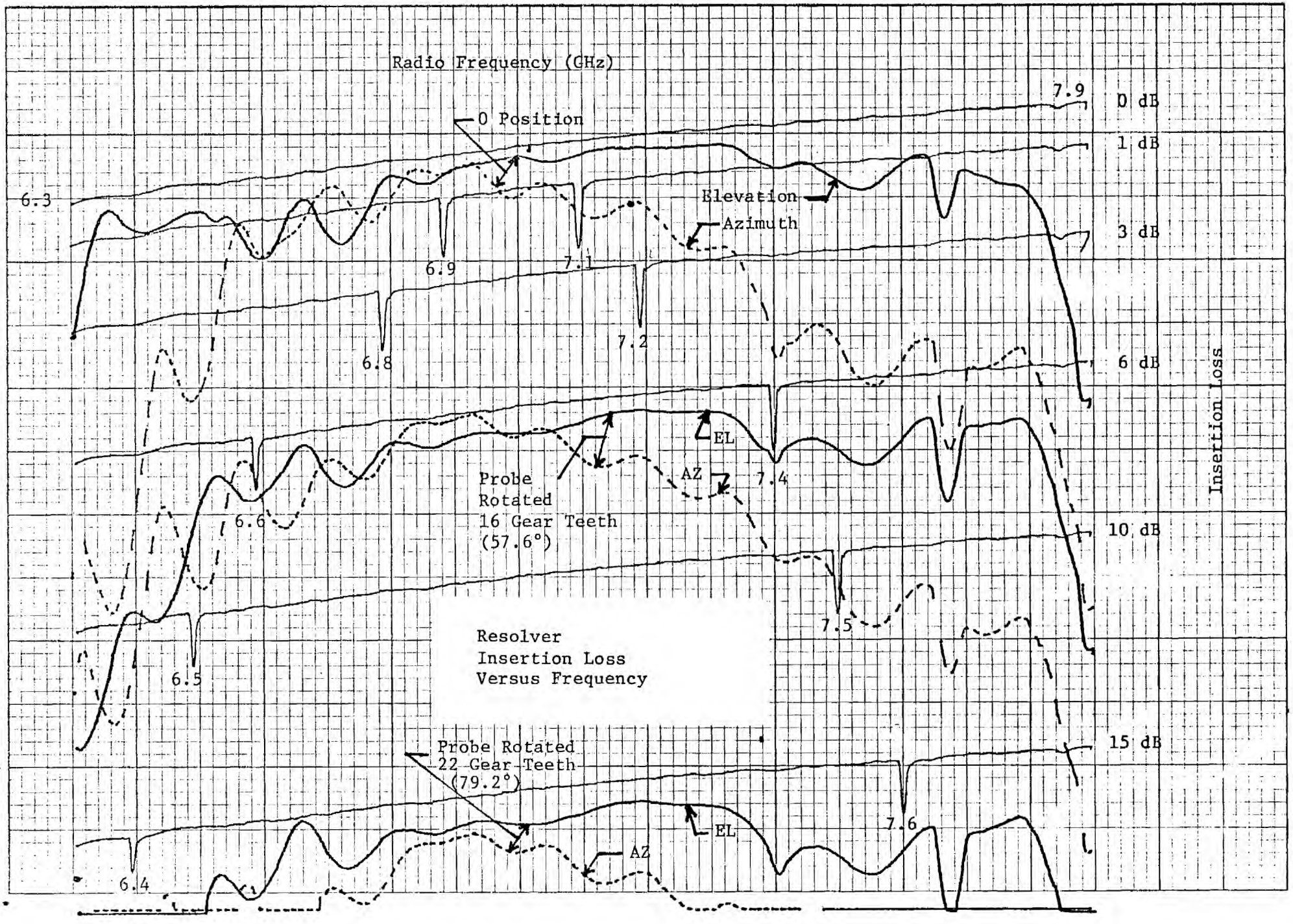
- A. Waveguide Filters
- B. Conversion Characteristics
  - (1) Mixer Alone
  - (2) Mixer Plus IF Amplifier

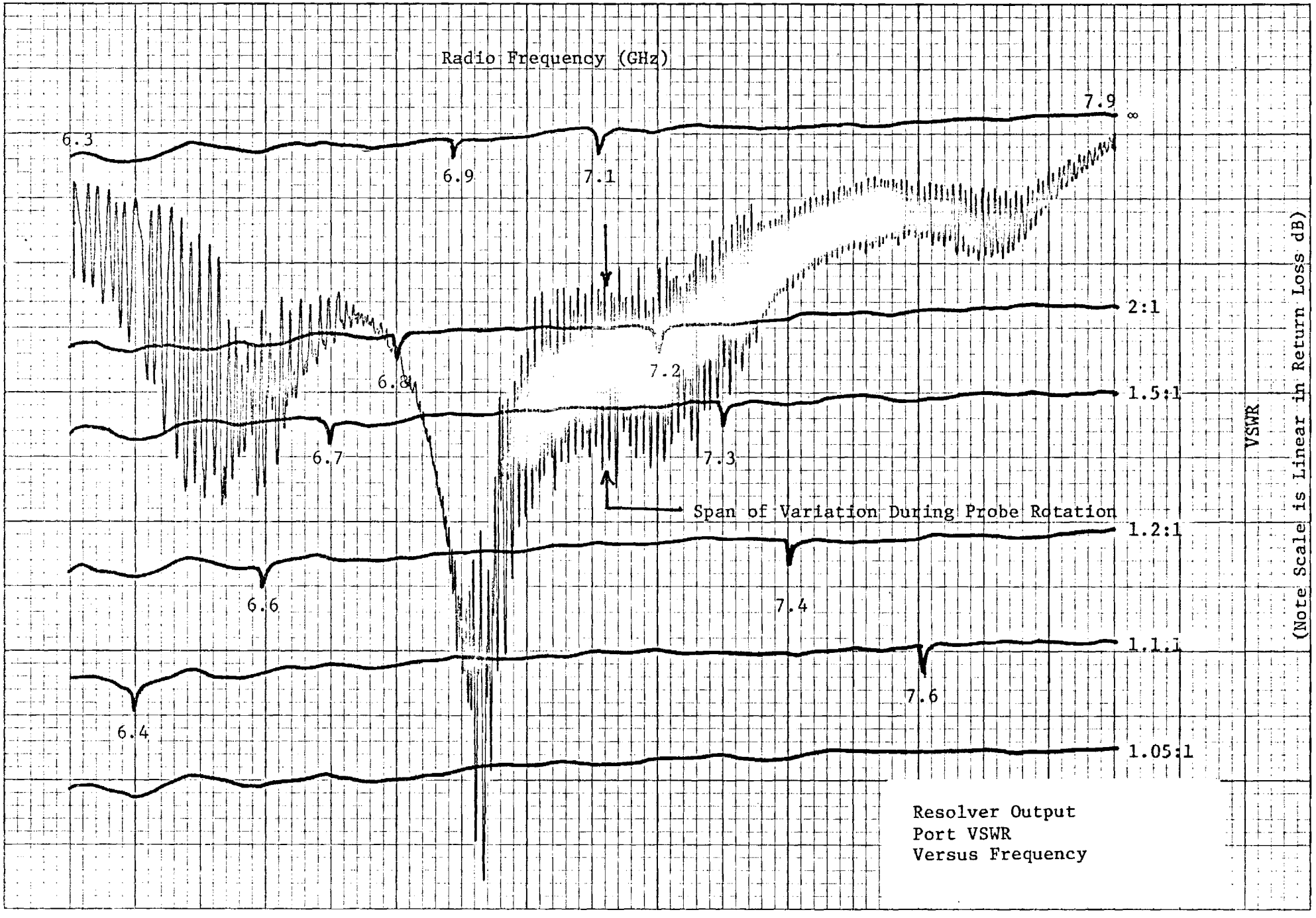
IV. Mixer/IF Amplifier Noise Figure

I. RESOLVER

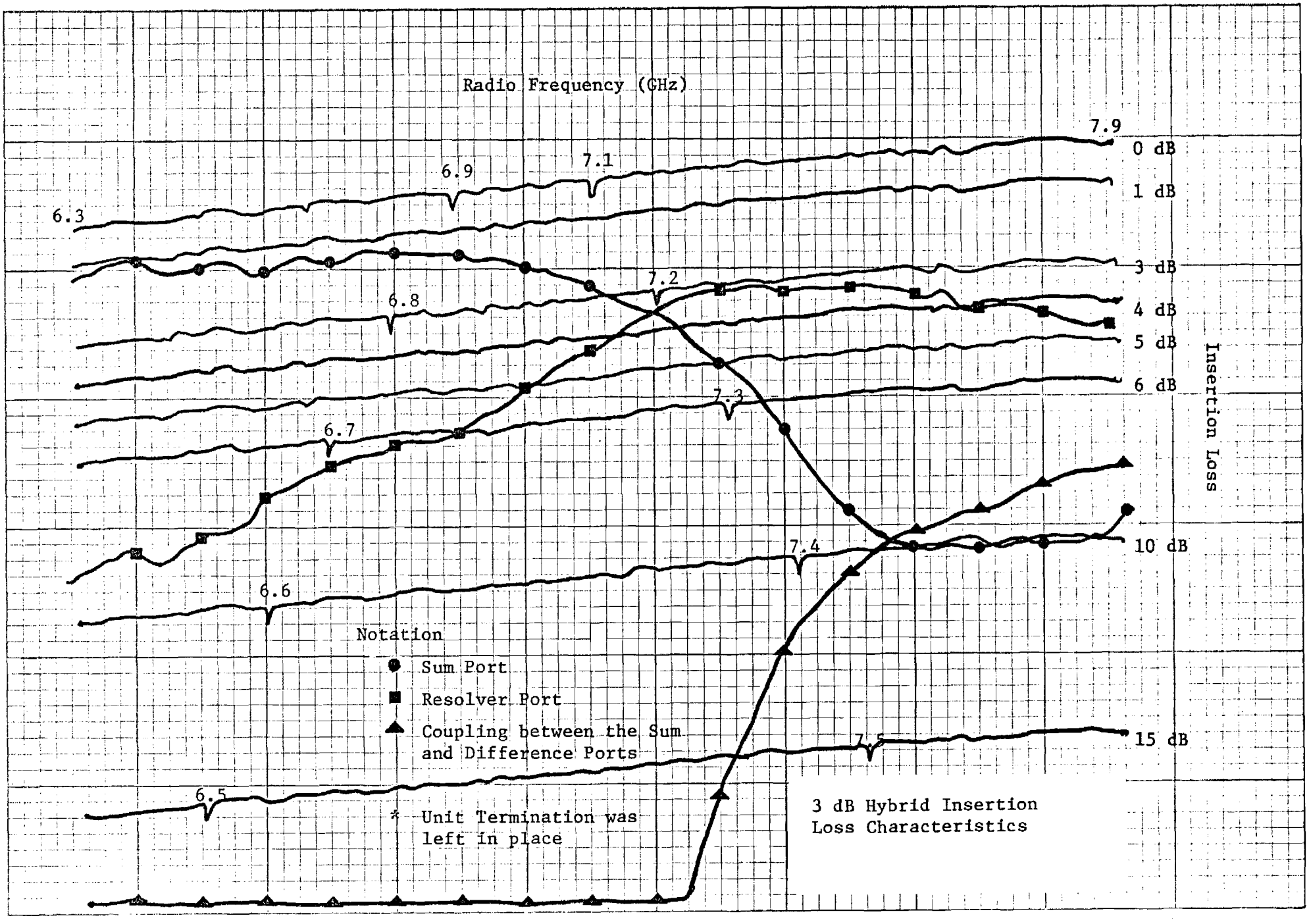


Resolver Input Ports VSWR Versus Frequency


Radio Frequency (GHz)
7.9
0 dB
0 Position
1 dB
6.3
Elevation
Azimuth
3 dB
6.9
7.1
6.8
7.2
6 dB
EL
Probe
Rotated
16 Gear Teeth
(57.6°)
AZ
7.4
6.6
10 dB
7.5
Resolver
Insertion Loss
Versus Frequency
6.5
Probe Rotated
22 Gear Teeth
(79.2°)
15 dB
EL
7.6
AZ
6.4
Insertion Loss


Radio Frequency (GHz)
6.3
6.4
6.6
6.7
6.8
6.9
7.1
7.2
7.3
7.4
7.6
7.9
∞
2:1
1.5:1
1.2:1
1.1:1
1.05:1
Span of Variation During Probe Rotation
VSWR
(Note Scale is Linear in Return Loss dB)
Resolver Output
Port VSWR
Versus Frequency

II. HYBRID


Radio Frequency (GHz)
6.3
6.5
6.6
6.7
6.8
6.9
7.1
7.2
7.3
7.4
7.5
7.9
0 dB
1 dB
3 dB
4 dB
5 dB
6 dB
10 dB
15 dB
Insertion Loss
Notation
Sum Port
Resolver Port
Coupling between the Sum and Difference Ports
* Unit Termination was left in place
3 dB Hybrid Insertion Loss Characteristics

III. MIXERS

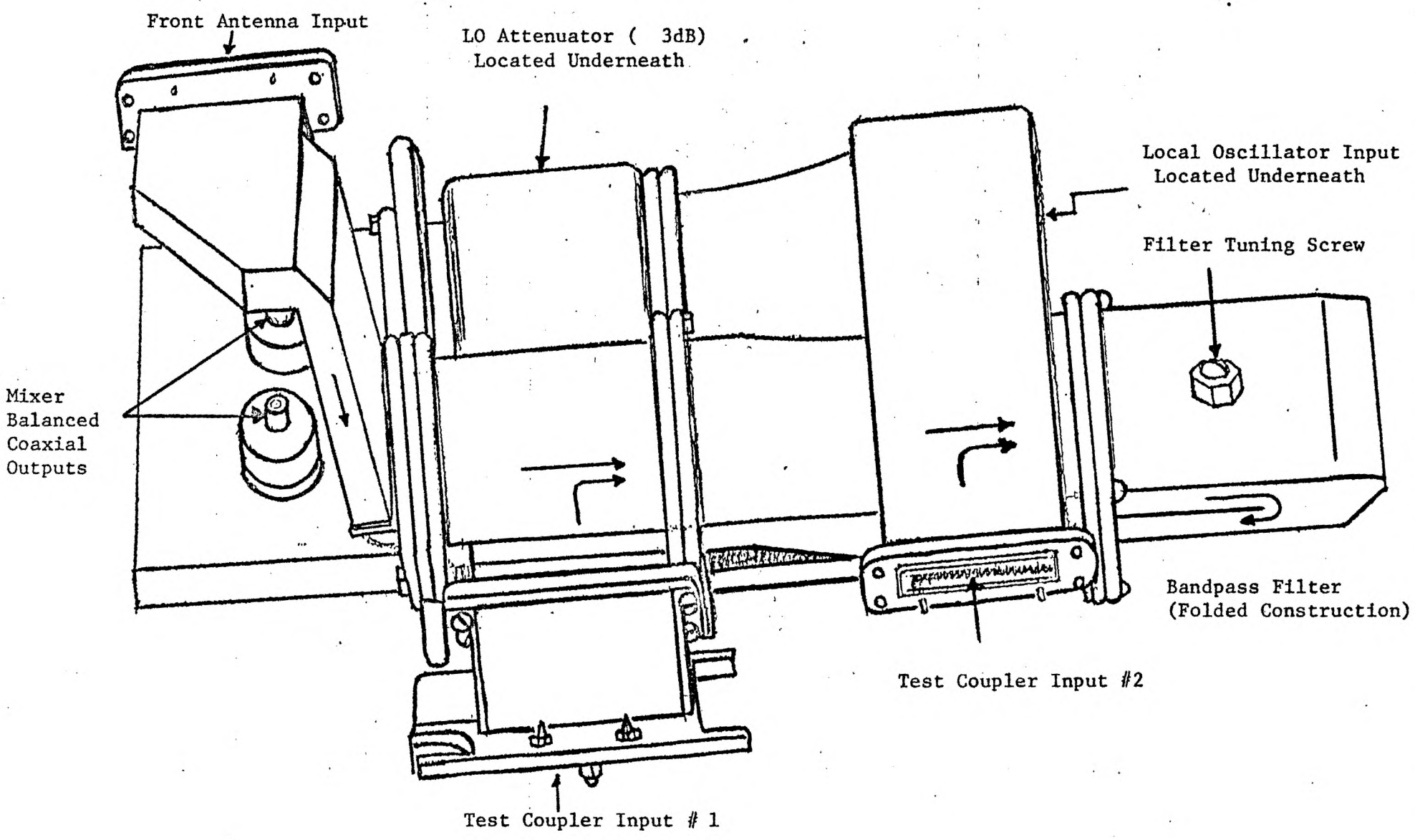


Figure 3-1: Front Mixer Sketch

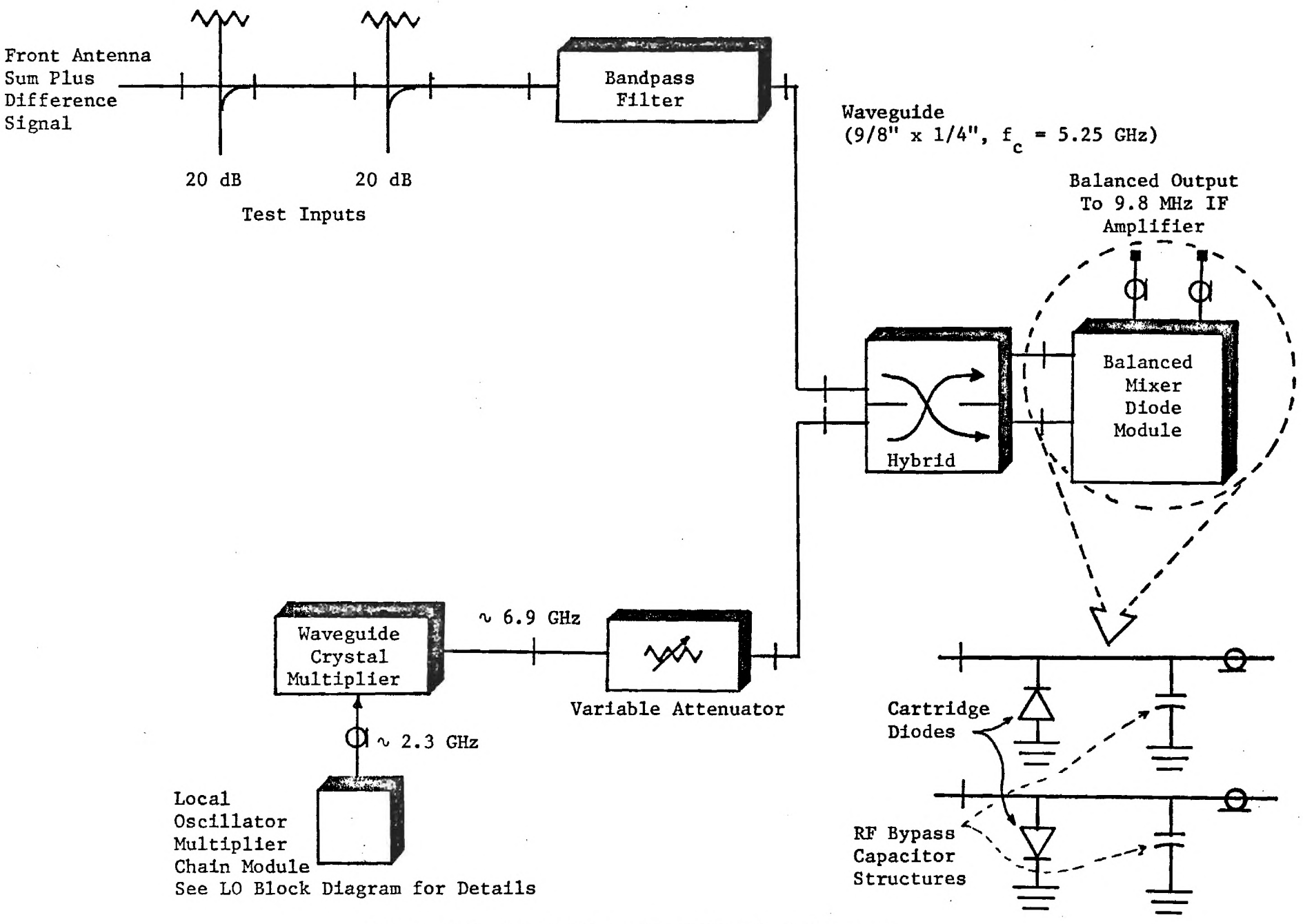


Figure 3-2: Front Mixer Assembly Block Diagram

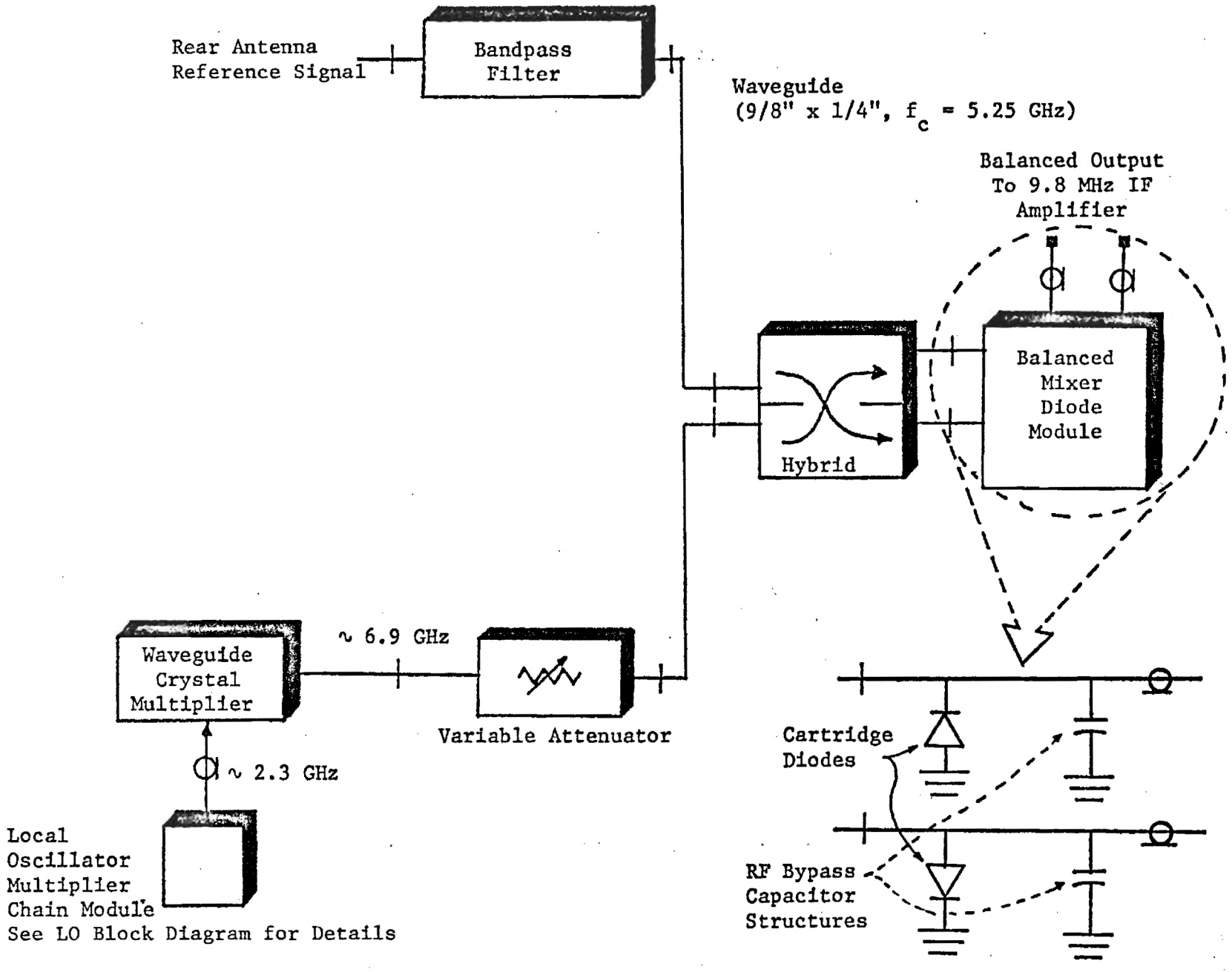
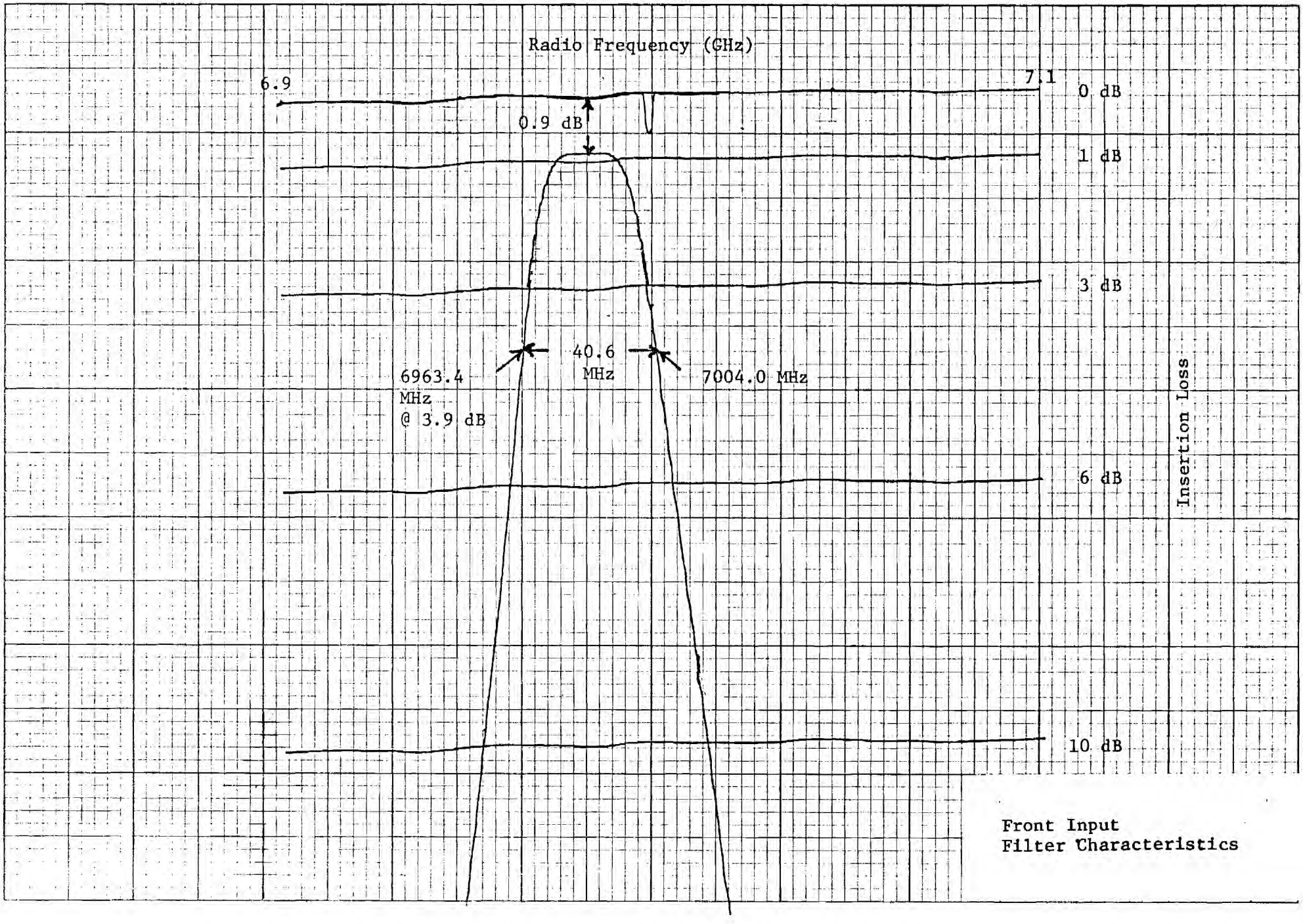
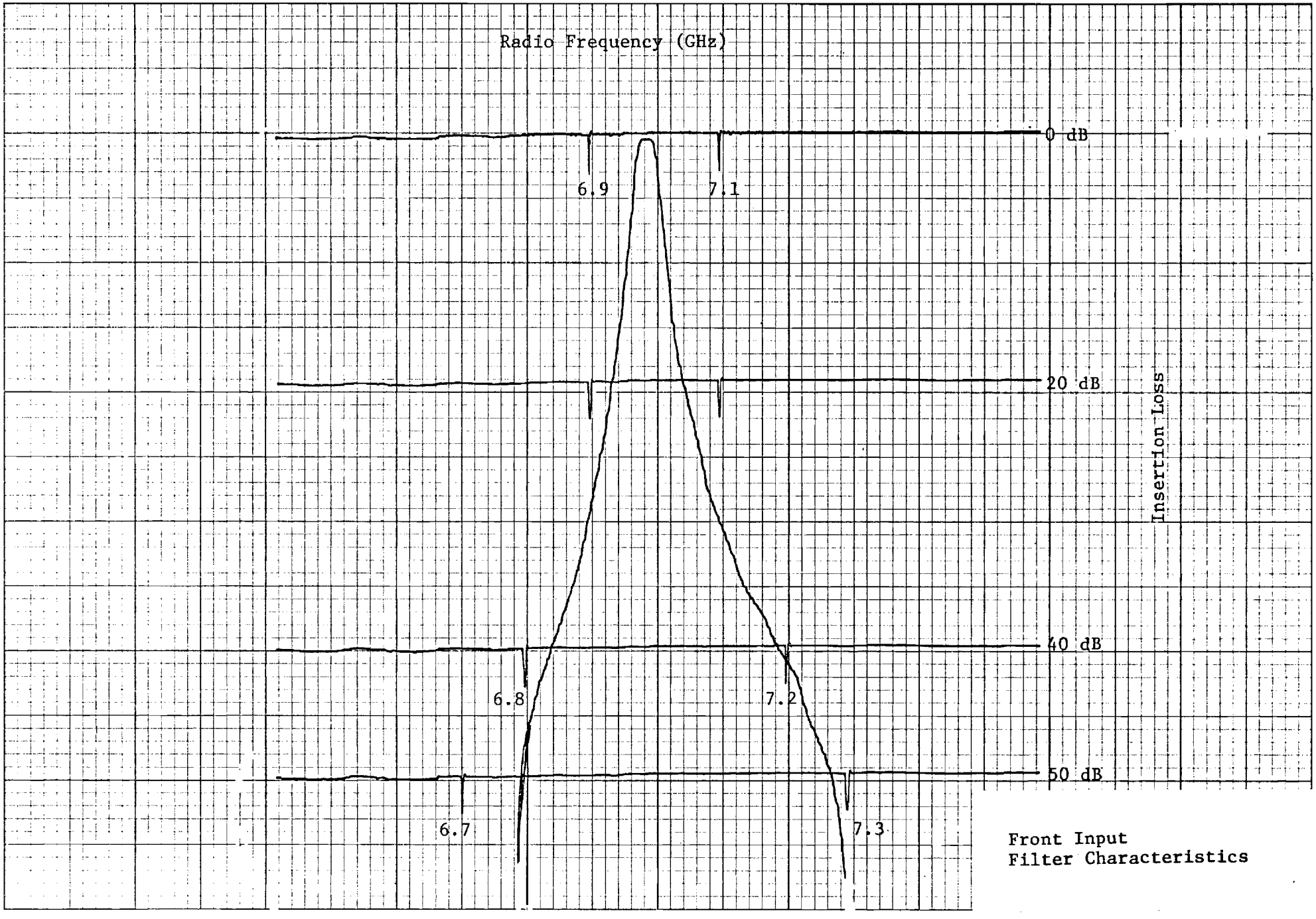


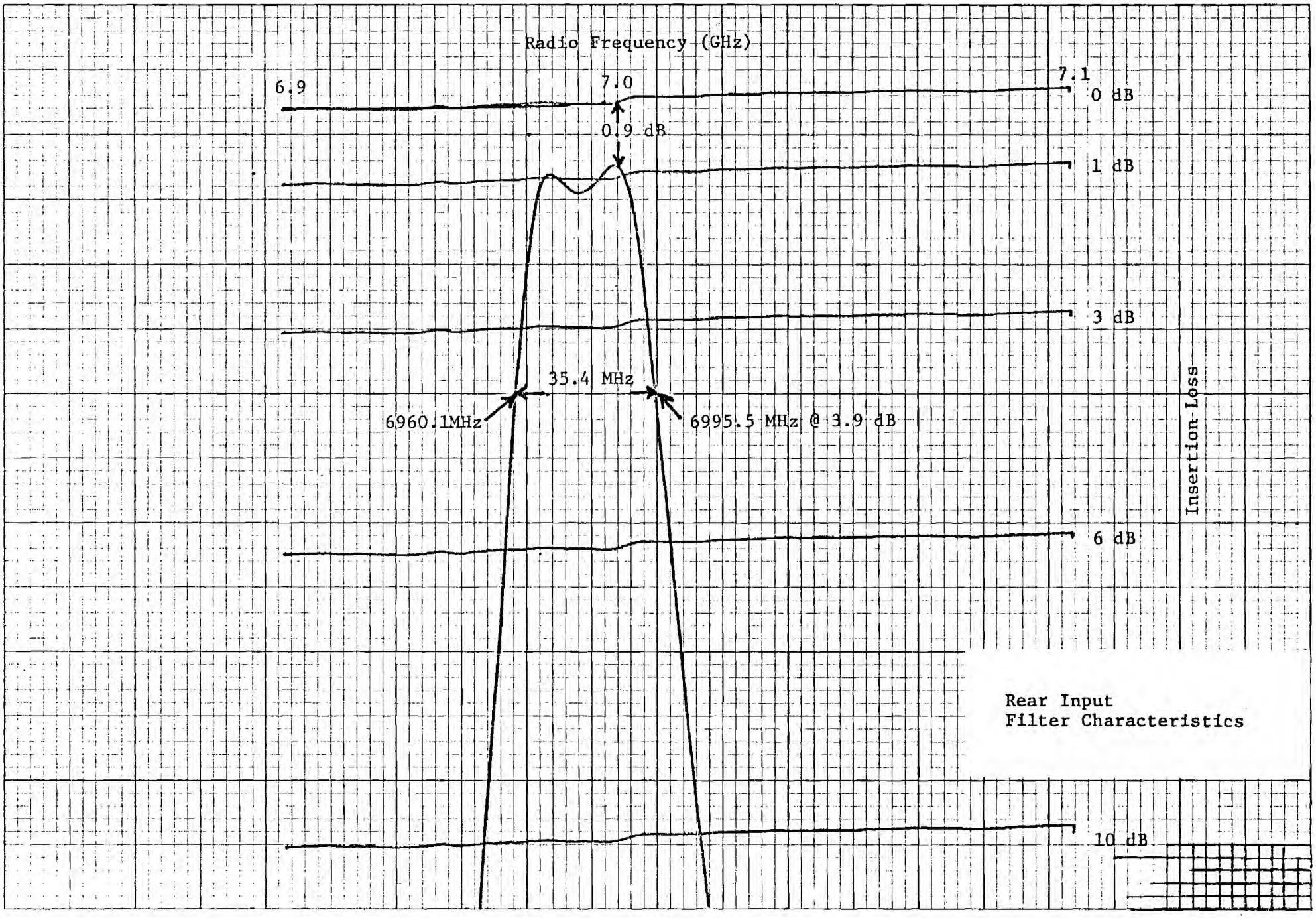
Figure 3-3: Rear Mixer Assembly Block Diagram

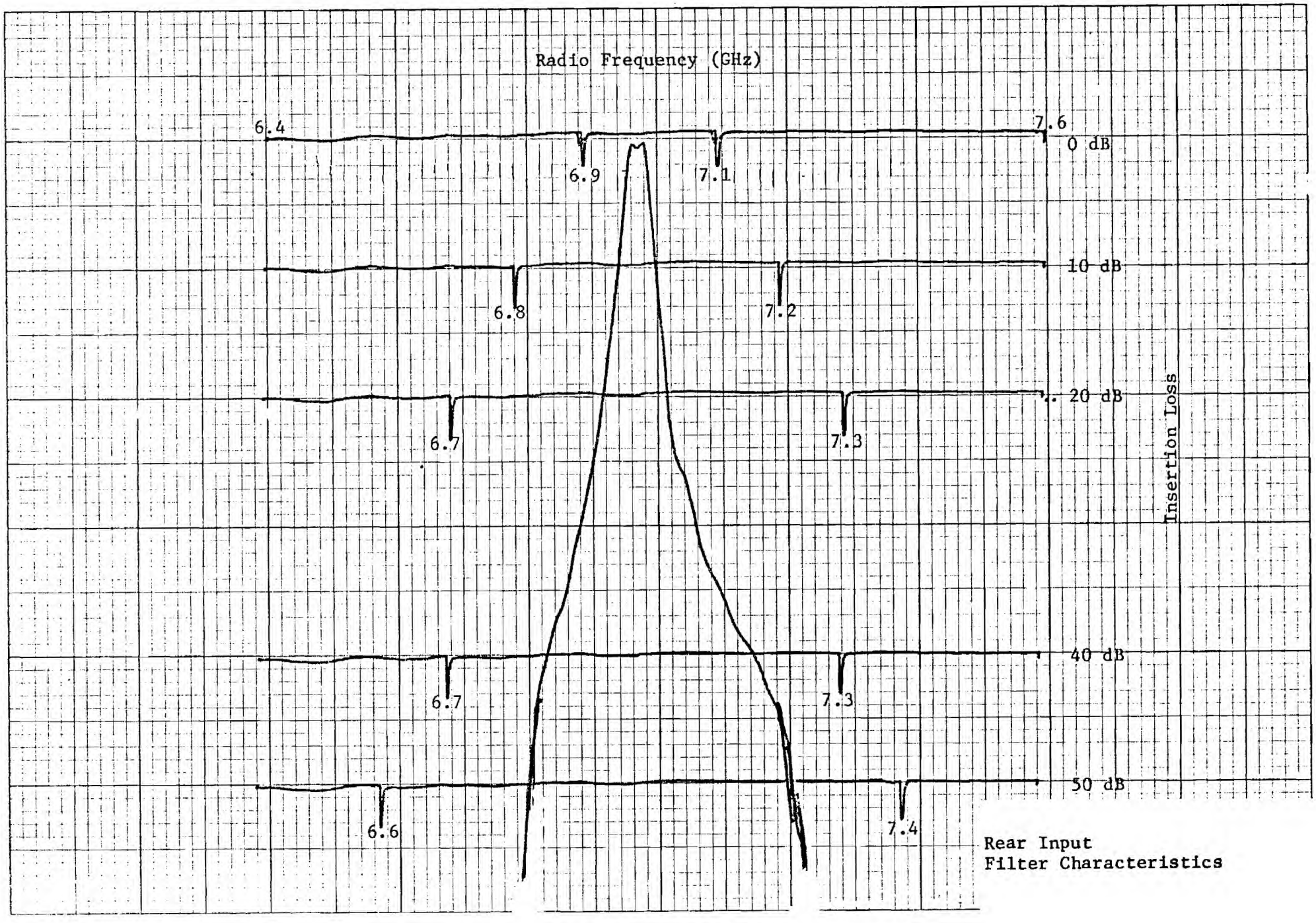


Front Input
Filter Characteristics

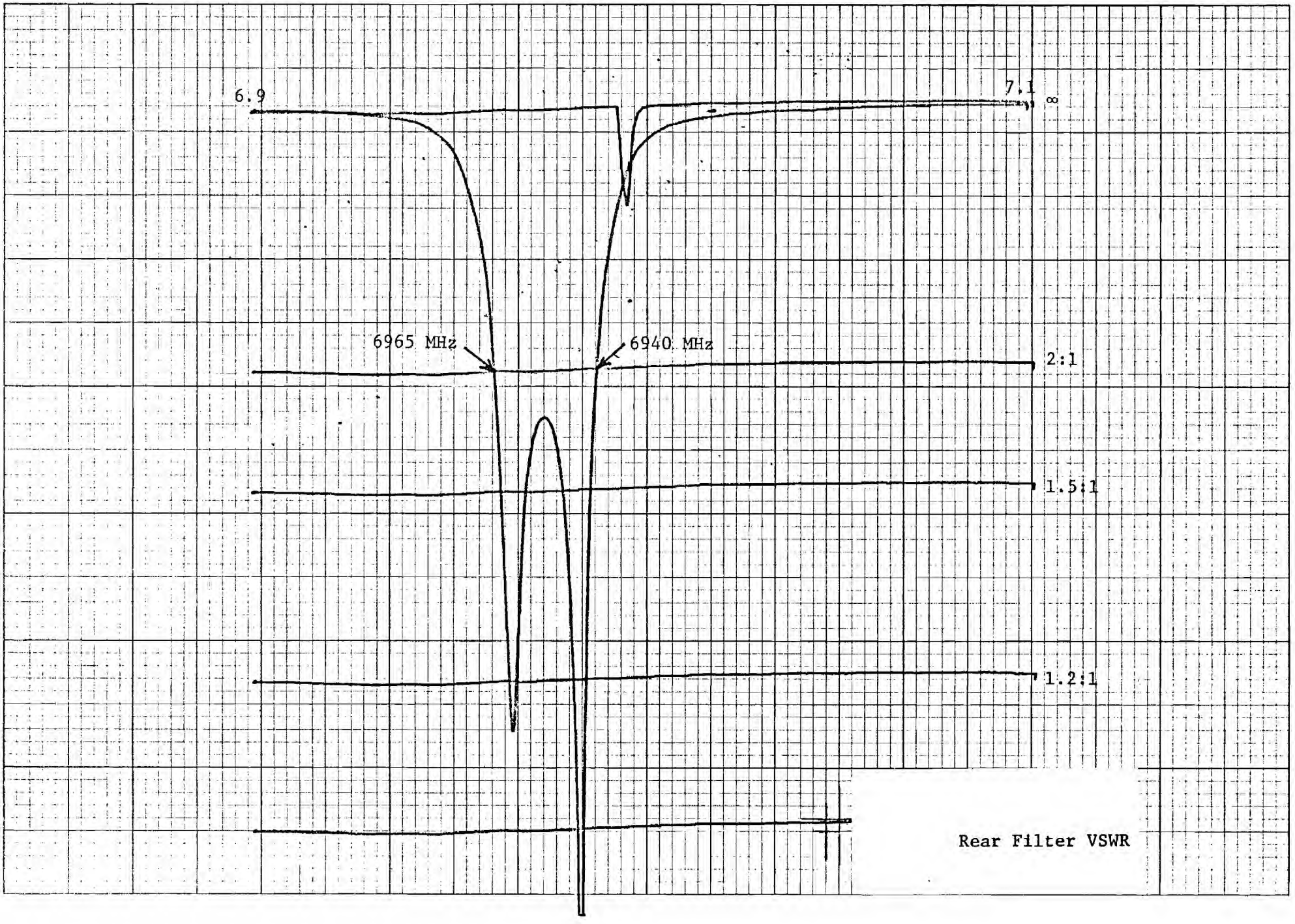


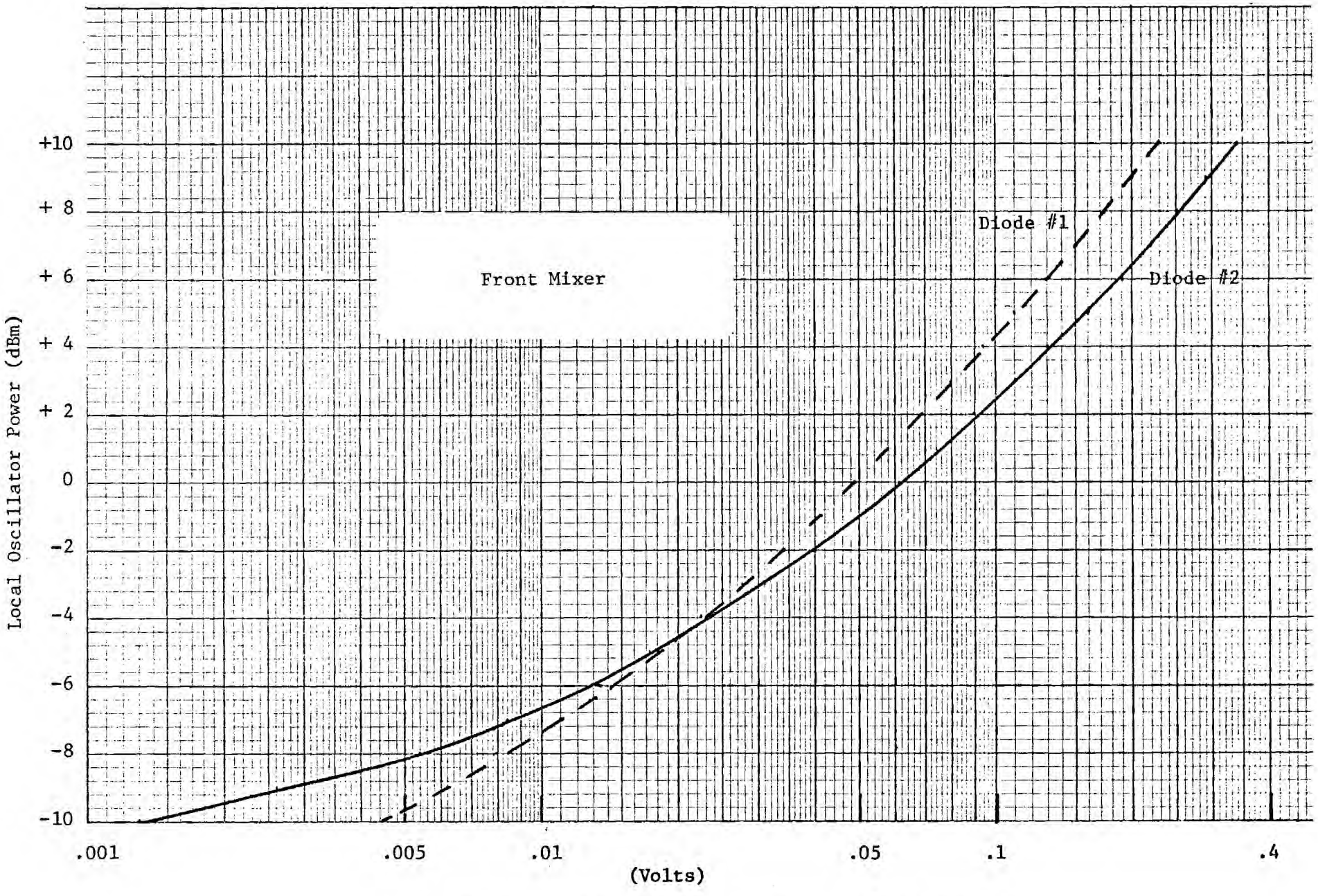
Front Input
Filter Characteristics


Radio Frequency (GHz)
6.9
7.0
7.1
0 dB
0.9 dB
1 dB
3 dB
35.4 MHz
6960.1MHz
6995.5 MHz @ 3.9 dB
Insertion Loss
6 dB
Rear Input
Filter Characteristics
10 dB



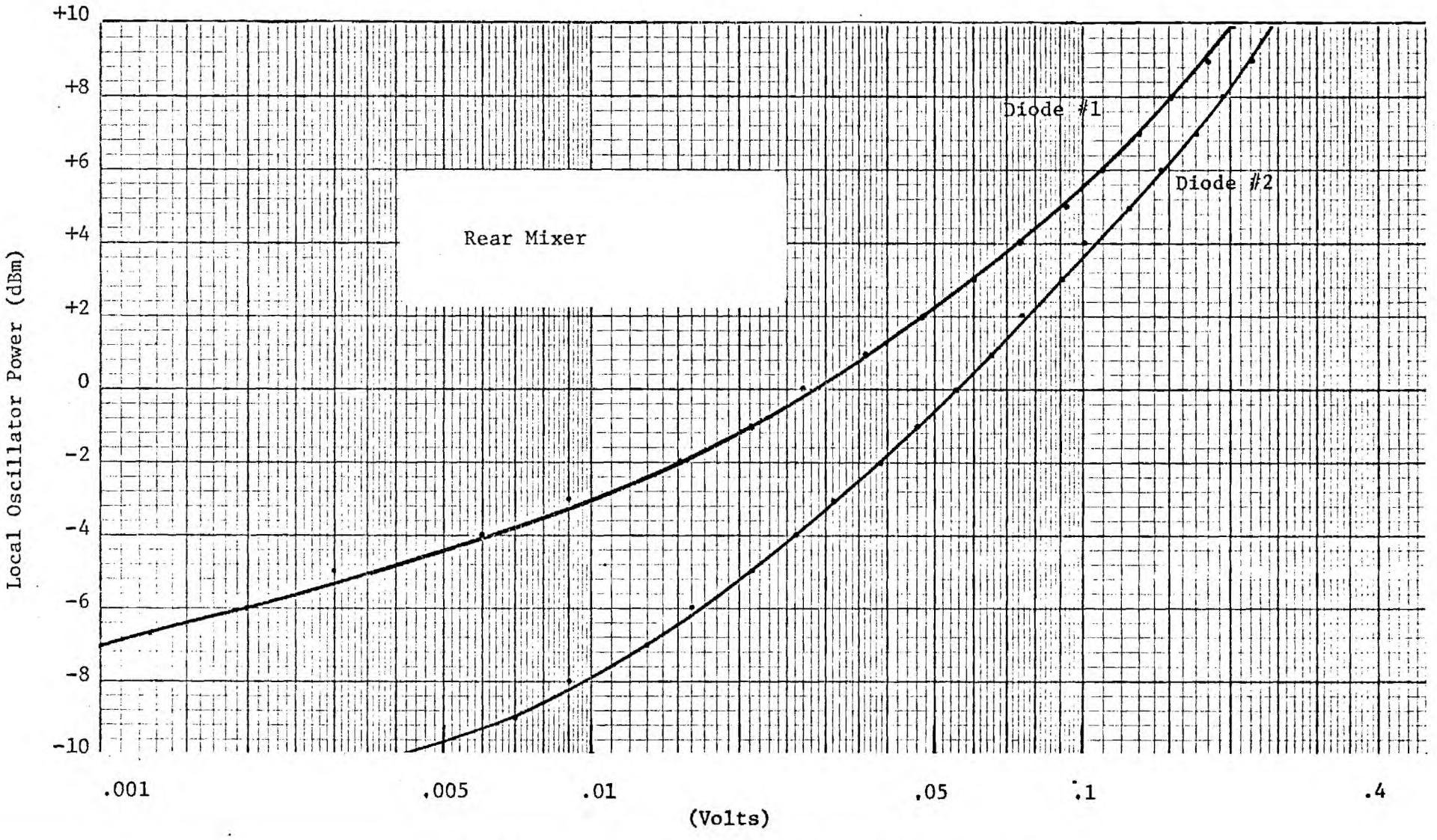
Rear Input
Filter Characteristics


6.9
7.1
∞
6965 MHz
6940 MHz
2:1
1.5:1
1.2:1
Rear Filter VSWR



Voltage developed across 100 ohms at test point

See Figure 3-5



Voltage developed across 100 ohms at test point

See Figure 3-5

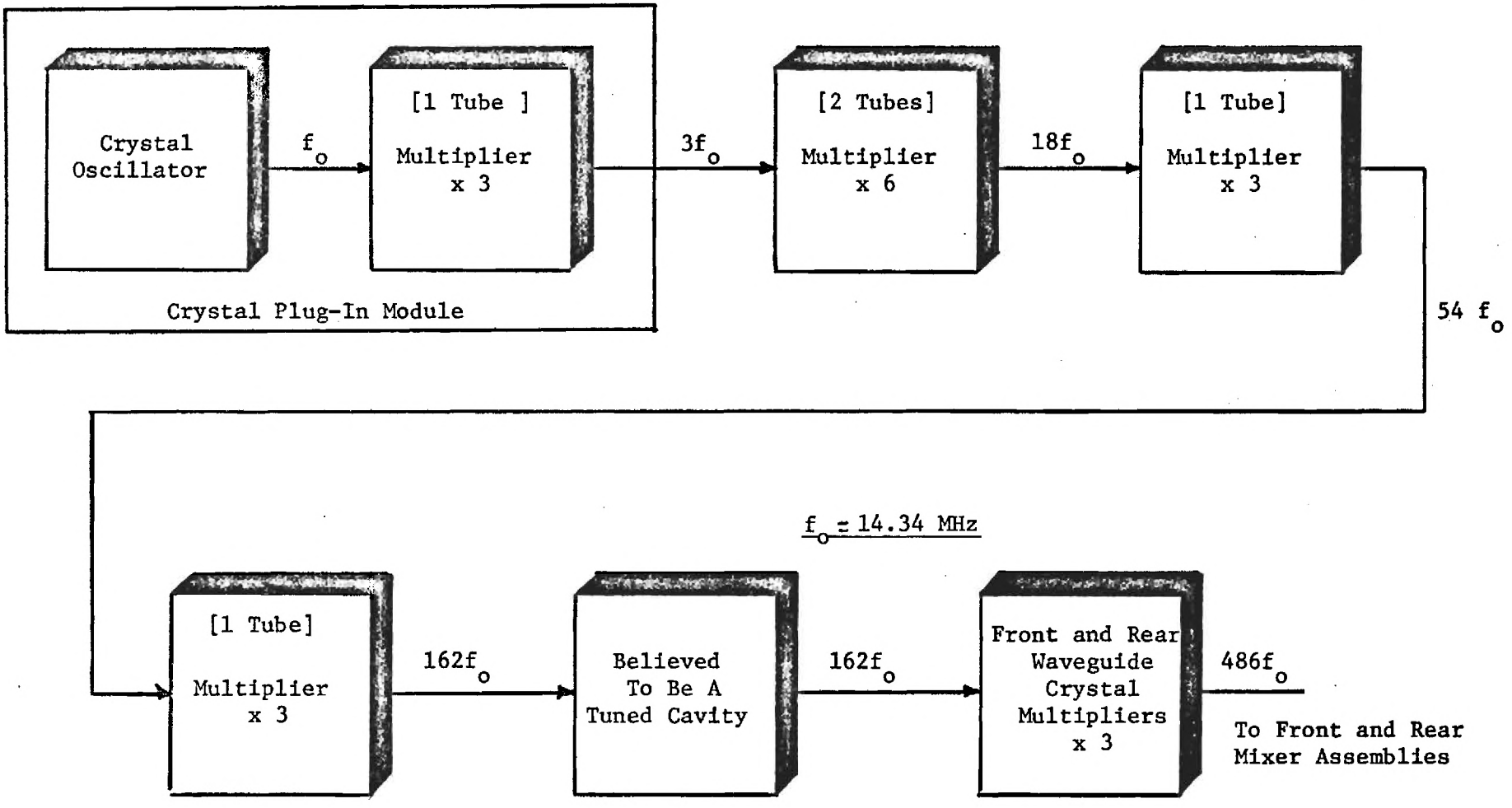


Figure 3-4: Local Oscillator Block Diagram

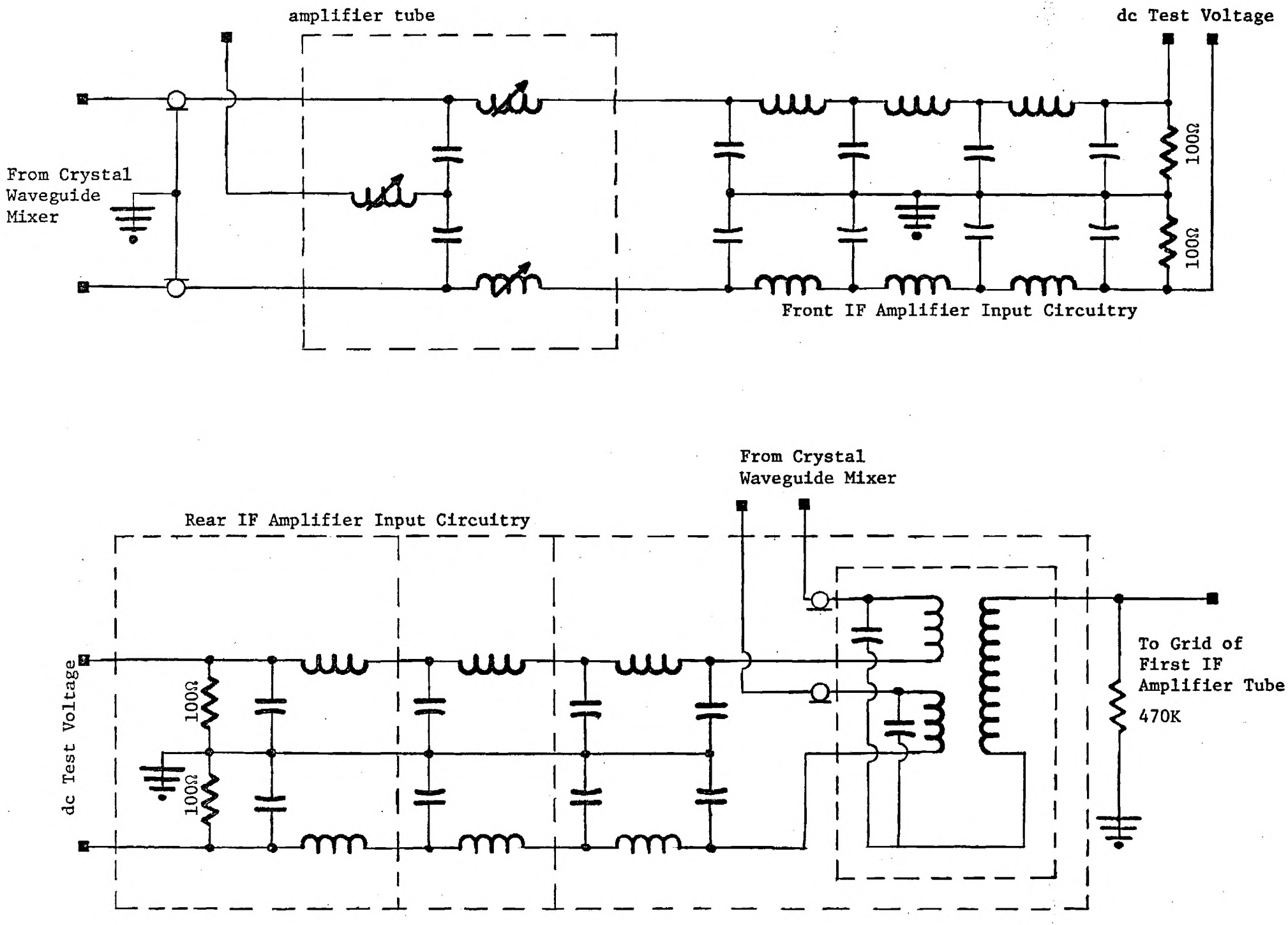
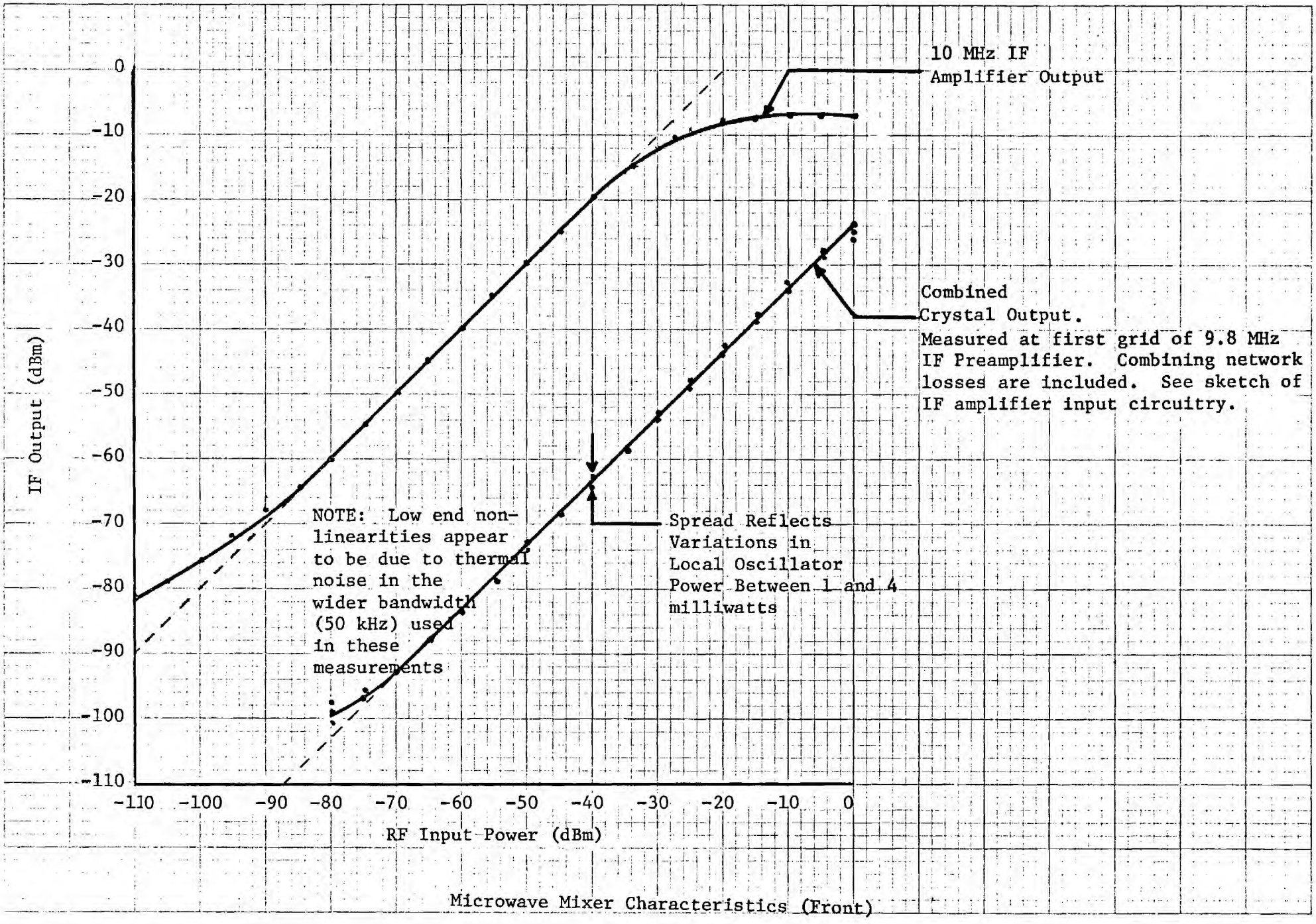
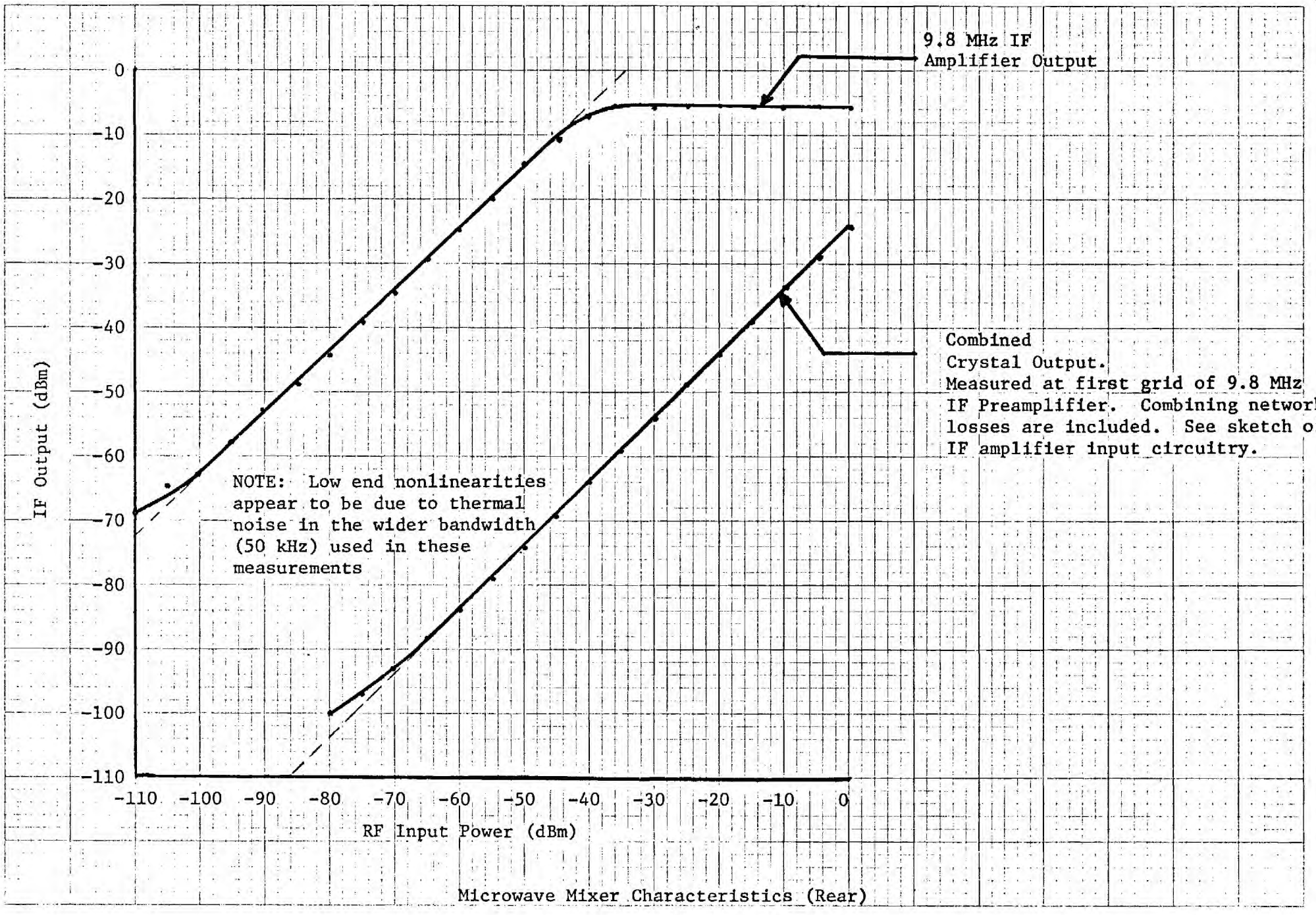

amplifier tube
dc Test Voltage
From Crystal
Waveguide
Mixer
100Ω
100Ω
Front IF Amplifier Input Circuitry
From Crystal
Waveguide Mixer
Rear IF Amplifier Input Circuitry
dc Test Voltage
100Ω
100Ω
To Grid of
First IF
Amplifier Tube
470K

Figure 3-5



Microwave Mixer Characteristics (Front)


9.8 MHz IF
Amplifier Output
Combined
Crystal Output.
Measured at first grid of 9.8 MHz IF Preamplifier. Combining network losses are included. See sketch of IF amplifier input circuitry.
NOTE: Low end nonlinearities appear to be due to thermal noise in the wider bandwidth (50 kHz) used in these measurements
IF Output (dBm)
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-110 -100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0
RF Input Power (dBm)
Microwave Mixer Characteristics (Rear)

IV. NOISE FIGURE

Noise Figure Measurement

In a conventional receiver, such as the one employed in this system, the image frequency channel does not contain any useful information. This channel does, however, contain thermal noise which will be summed with the thermal noise present in the signal channel when the radio frequency is down converted to the intermediate frequency. This is referred to as the Single Sideband (SSB) situation in mixer noise figure characterization. When the signal occupies both the upper and lower sidebands as is the case when the wideband excess noise generator is used, the double sideband (DSB) notation is employed. Consequently, the noise figure of the system when measured will be a DSB noise figure and the SSB noise figure is 3 dB poorer than the value that would be found if the noise source spectrum was limited to only the signal channel. These remarks are summarized in Table I.

The noise figure of the input waveguide, filter, mixer, and IF amplifier combination was measured using an AIL type 7616 solid state noise source as shown in Figure 1. The filter assembly contributed about 1 dB to the noise figure data given below. This noise source with an excess noise ratio of 15.1 dB at the nominal f_o frequency was connected to the mixer waveguide input via a coax to waveguide adapter. Output power of the IF amplifier was then measured with the noise source on and off. The "Y" factor of the system was obtained by taking the difference between these two output states. This factor was converted into an equivalent noise figure for the system by the following expression:

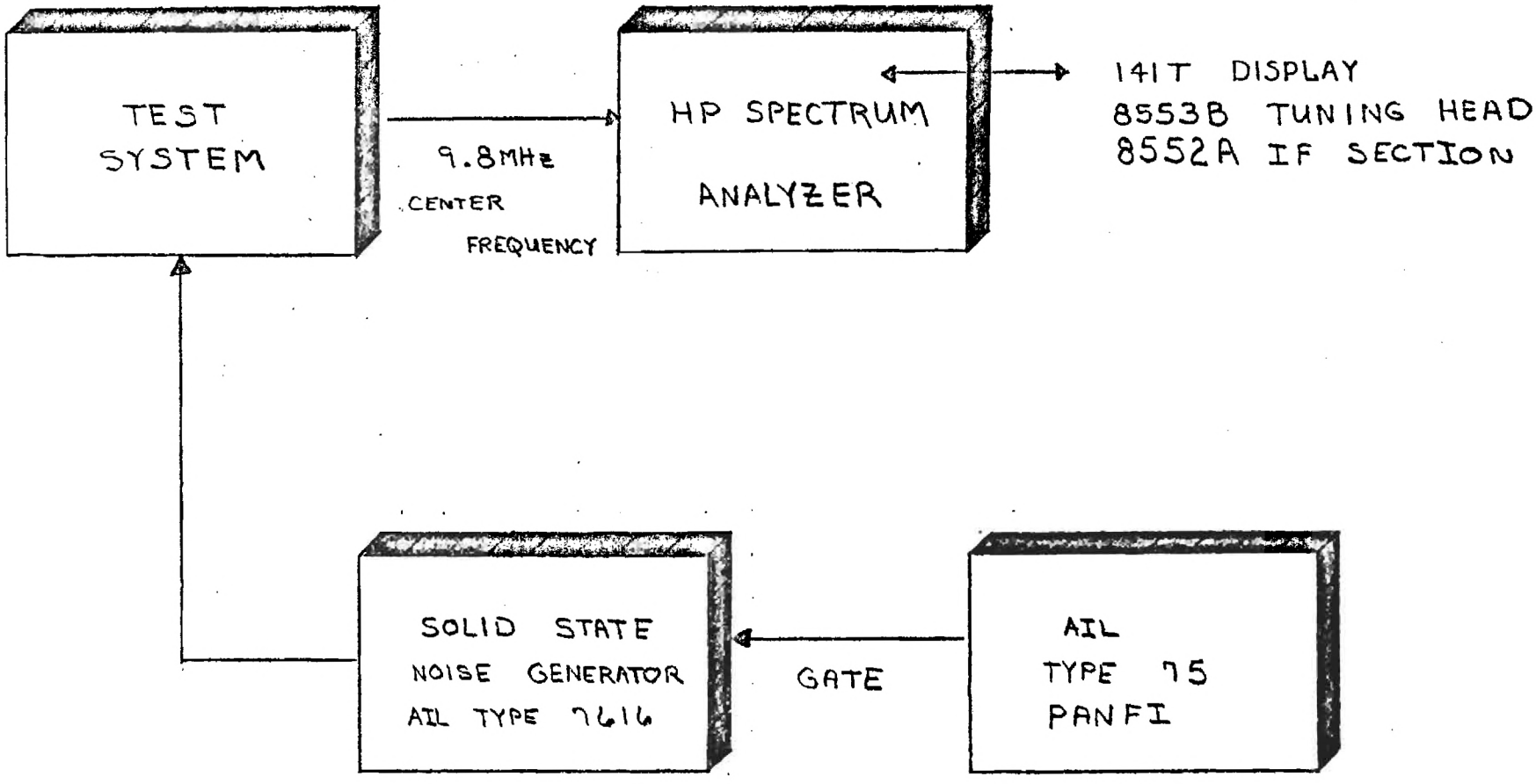
$$F_{dB}(DSB) = ENR(dB) - 10 \log_{10} (Y - 1).$$

Average SSB noise figures of 12.8 dB and 13.4 dB were found for the front and rear assemblies, respectively. System noise figures would still be higher because of losses from the antenna to the mixer input. While all of these losses are not known for the rear (reference) paths the front channel losses are itemized below: antenna grid losses $\approx$0.3 dB, feed losses $\approx$0.1 dB, flexible cable losses $\approx$1 dB maximum, resolver losses 0.5 dB, VSWR $\approx$0.2 dB for a total of 2.1 dB. Thus the effective system noise figure of the front channel is 12.8 dB + 2.1 dB = 14.9 dB.

The noise figure of the rear assembly was measured at several values of local oscillator drive to determine the optimum value. Optimum being defined as the lowest noise figure. This level is often about 0.5 MW at the crystal. Using a local oscillator power of 2 MW and accounting for local oscillator padding and mixer hybrid coupler losses, it was found that approximately 0.5 MW was applied to each mixer crystal when the lowest noise figure was measured. Similar results could be expected for the front channel.

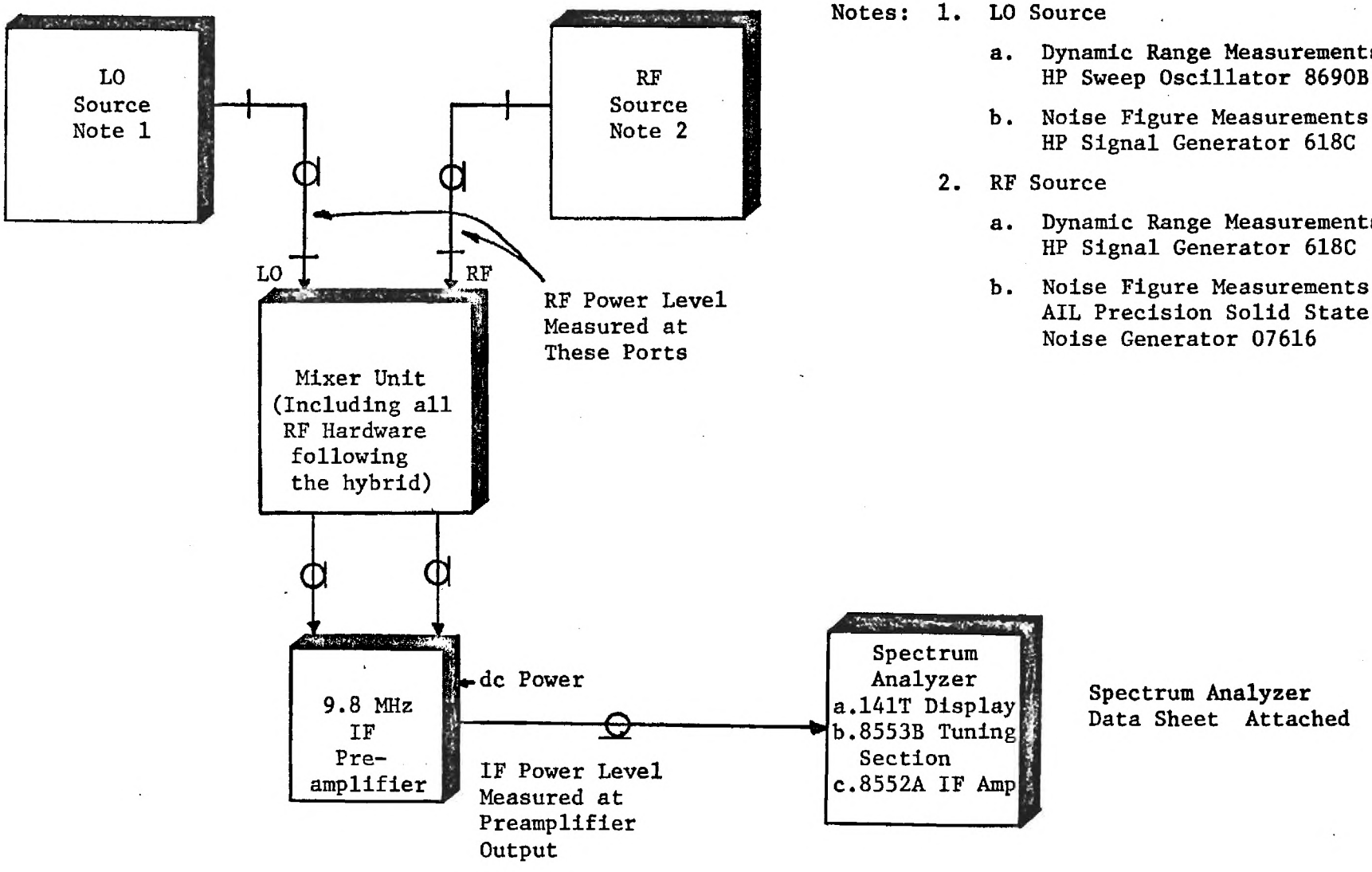
TABLE I

Noise Figure	Situation	Remarks
SSB	Signal only in one side band, thermal noise in both	Normal conditions for the operational system
DSB	Signal in both side bands, thermal noise in both	Wide band noise source used in measurements cover both side bands



SET UP FOR MEASURING NOISE FIGURE

Figure 4-1

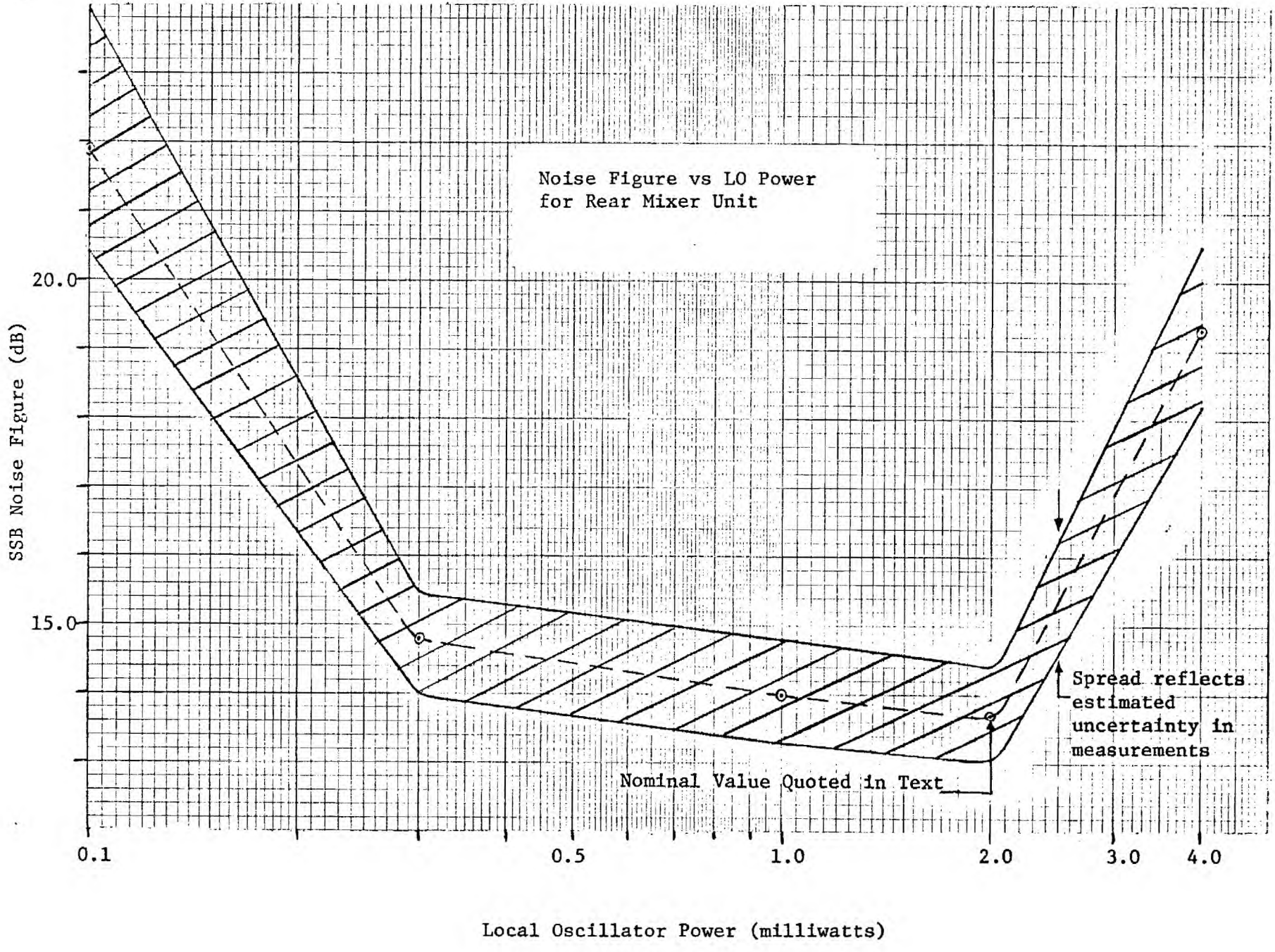


Notes:

1. LO Source
   a. Dynamic Range Measurements
      HP Sweep Oscillator 8690B
   b. Noise Figure Measurements
      HP Signal Generator 618C
2. RF Source
   a. Dynamic Range Measurements
      HP Signal Generator 618C
   b. Noise Figure Measurements
      AIL Precision Solid State
      Noise Generator 07616

Test Equipment Arrangement for Mixer Evaluation

Figure 4-2


Noise Figure vs LO Power
for Rear Mixer Unit
20.0
15.0
SSB Noise Figure (dB)
Spread reflects
estimated
uncertainty in
measurements
Nominal Value Quoted in Text
0.1
0.5
1.0
2.0
3.0
4.0
Local Oscillator Power (milliwatts)

Partial Specifications 8553B/8552A
RF and IF Sections

(refer to Technical Data Sheet for complete specifications)

RF input and tuning characteristics

Frequency range: 1 kHz to 110 MHz. Tuning dials calibrated for 0-110, 0-11 MHz.

Frequency response: ±0.5 dB, 1 kHz to 110 MHz (for attenuator settings ≥10 dB). Typical fine grain flatness, ≤0.1 dB per MHz.

Input impedance: 50Ω nominal. Reflection coefficient ≤0.13. (1.3 SWR) for input attenuator setting ≥10 dB.

Maximum input level: peak or average power to input mixer < +13 dBm (1.4 V ac peak; ±50 V dc).

Noise level: the average noise level of the analyzer depends on IF bandwidth and determines its sensitivity for small signals, see Figure 3.

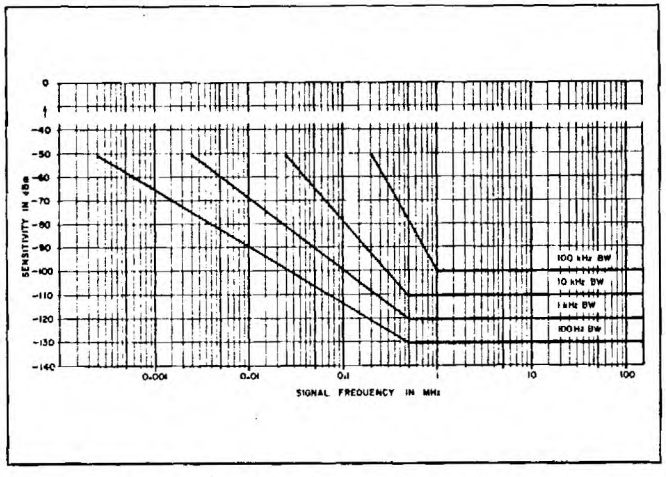


Figure 3. Noise level vs. Input Frequency.

Amplitude characteristics

Vertical display calibration (8 divisions full-scale deflection)

Logarithmic: calibrated directly in dBm over 140-dB range from −130 dBm to +10 dBm, 10 dB/div on 0 to −70 dB CRT display. Measurement accuracy at least ±1.5 dB using suitable measurement techniques.

Linear: calibrated directly in V/div from 0.1 μV/div to 100 mV/div in a 1, 2, 10 sequence.

Calibrator: 30-MHz signal, −30 dBm ±0.3 dB.

Spectral resolution

IF bandwidth: 3-dB bandwidths of 50, 100, 300 Hz, and 1, 3, 10, 30, 100, and 300 kHz can be selected.

IF bandwidth selectivity: 60 dB/3 dB bandwidth ratio less than 20:1 for IF bandwidths from 1 kHz to 300 kHz. 60 dB/3 dB bandwidths ratio less than 25:1 for IF bandwidths from 50 Hz to 300 Hz.

Video filter bandwidths: 10 kHz and 100 Hz.

Spectral purity

Stabilization: automatic phase-lock reduces residual FM to less than 20 Hz peak-to-peak for scans 20 kHz/div or less.

Noise sidebands: more than 70 dB below CW signal 50 kHz or more away from signal, with a 1-kHz IF BANDWIDTH setting.

Spurious responses: for −40 dBm signal level to input mixer: image responses, out-of-band mixing responses, harmonic and intermodulation distortion products, and IF feedthrough responses, all more than 70 dB below the Signal Level at Input Mixer. (Signal Level at RF INPUT — INPUT ATTENUATOR).

Residual responses: 200 kHz to 110 MHz: <−110 dBm. 20 kHz to 200 kHz: <−95 dBm.

Scan characteristics

Scan width: 20 Hz/div to 10 MHz/div in a 1, 2, 5, sequence plus ZERO and preset 0-100 MHz scan.

Scan time: 0.1 ms/div to 10 s/div in a 1, 2, 5, sequence.